W. B. No. 793.

U. S. DEPARTMENT OF AGRICULTURE

WEATHER BUREAU

U.S.

MONTHLY WEATHER REVIEW

1

VOLUME 50, No. 12

DECEMBER, 1922

WASHINGTON
GOVERNMENT PRINTING OFFICE
1923

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MONTHLY WEATHER REVIEW

ALFRED J. HENRY, Editor.

VOL. 50, No. 12.
W. B. No. 793.

DECEMBER, 1922.

CLOSED FEBRUARY 3, 1922.
ISSUED MARCH 9, 1923.

DAYLIGHT ILLUMINATION ON HORIZONTAL, VERTICAL, AND SLOPING SURFACES.[1]

By HERBERT H. KIMBALL and IRVING F. HAND.

[Weather Bureau, Washington, January 10, 1923.]

SYNOPSIS.

The report summarizes sky-brightness and daylight-illumination measurements made during the year ending April 6, 1922: For 10 months the measurements were made in a suburb of Washington that is comparatively free from city smoke. During the other 2 months, one in summer and one in winter, the measurements were made in the smoky atmosphere of the city of Chicago.

The measurements were made as nearly as possible with the sun at altitudes above the horizon of 0°, 20°, 40°, 60°, and 70°. From the sky-brightness measurements the resulting illumination on vertical surfaces differently oriented with respect to the sun, and on surfaces sloping at different angles and in different directions, has been computed. These computed values have been utilized, in connection with daylight-illumination measurements, to construct charts showing for latitude 42° north, illumination intensities for each hour of each day of the year as follows:

(1) On a vertical and on a horizontal surface, from a cloudy sky.

(2) On a horizontal surface and on vertical surfaces facing the eight principal points of the compass, from a clear sky.

(3) On a horizontal surface and on vertical surfaces facing the eight principal points of the compass, from the sun and clear sky combined.

The illumination on sloping surfaces from skylight and from solar and skylight combined has been summarized in tables.

The application of these data to the lighting of working space in a building through saw-tooth roof construction is shown. It is pointed out that with a clear sky the larger proportion of the illumination should result from the reflection of light from the outside roof surface through the window opening, rather than by the direct transmission of skylight through the window.

With a cloudy sky the illumination on a horizontal surface is considerably more than twice that on a vertical surface, due to the fact that the region of maximum brightness is in or near the zenith.

With high sun, as at midday in summer, the illumination from a cloudy sky averages higher than the illumination from a clear sky, except on a vertical surface facing the sun. This is not the case with low sun.

The maximum illumination from a clear sky on vertical surfaces is a little in excess of 1,400 foot-candles, and occurs on surfaces facing the sun from early June to early September, between the hours of 8:30 a. m. and 3:30 p. m.

The minimum illumination from skylight is on a vertical surface facing away from the sun. At Chicago in the smoky Loop District the illumination from a cloudless sky on such a surface averages about 2/3 the illumination at Washington on a similar surface from a clear sky.

The total (solar+sky) illumination generally increases on surfaces sloping toward the south until the angle of slope reaches 20°, except with low sun during the summer months. The maximum is about 11,000 foot-candles at noon in midsummer.

At Washington the illumination from a clear sky on both horizontal and vertical surfaces varies between 150 and 60 per cent of the average values; from a cloudy sky, between 200 and 30 per cent; from a sky partly covered with white clouds, on a horizontal surface three to four times, and on a vertical surface two to three times that from a clear sky; with rain falling, about half that from a cloudy sky.

SKY BRIGHTNESS AND DAYLIGHT ILLUMINATION MEASUREMENTS.

In a report of this committee[2] presented at the Rochester meeting in September, 1921, the program of sky-brightness measurements was outlined, and some preliminary results were given. The program of a full year of sky-brightness measurements was completed on April 6, 1922. During four weeks ending with August 13, 1921, and a second four weeks ending with February 2, 1922, the measurements were made in the city of Chicago. During the remainder of the year they were made in a suburb of the city of Washington that is practically free from city smoke.

As was explained in the previous report, at Washington the photometer was mounted on a stand inside a small shelter that was painted white on the outside and flat black on the inside. The upper edge of the sides of the house is on a level with the center of the elbow tube of the photometer when the latter is horizontal. This exposure permits measurements of the illumination from skylight on both horizontal and vertical surfaces. With a clear sky, however, illumination measurements on vertical surfaces have been confined to surfaces facing in azimuth 0° and 45° from the sun, as at greater azimuths the blackened inside walls of the shelter reflect too much sunlight to the photometer.

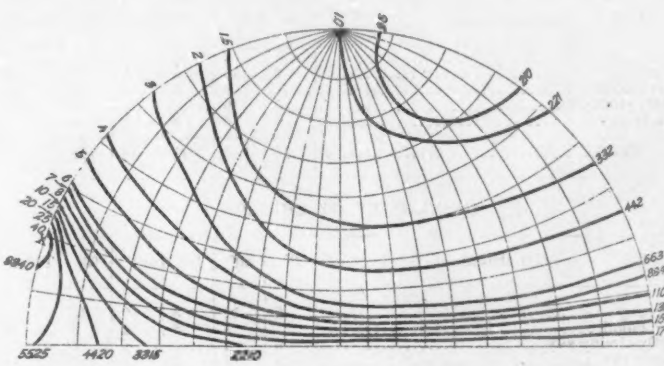


FIGURE 1.—Sky brightness in millilamberts. Sun's position indicated by X. Washington, D. C., cloudless sky, ground covered with snow.

It may be well to recall to mind some details of the sky-brightness measurements. Figure 1 is a stereographic projection of the half of the sky on either side of the sun's vertical. The sun's position is indicated by the letter X. The horizontal straight line represents the horizon, and above it are lines of equal altitude 10° apart. Extending from the zenith to the horizon are azimuth circles also 10° apart.

A complete series of sky-brightness measurements consists of three photometric readings on each of the points at 2°, 15°, 30°, 45°, 60°, 75°, and 90° above the horizon, and on azimuth circles 0°, 45°, 90°, 135°, and 180° from the sun, covering half the sky only. Unless the sky is cloudy the point that falls nearest the sun on azimuth circle 0° is usually too bright to measure with the screens

[1] Report of the committee on sky brightness of the Illuminating Engineering Society, H. H. Kimball, chairman. Presented at the annual convention, Swampscott, Mass., September 28, 1922; later, revised and extended.

[2] Transactions Illum. Engr. Soc., Oct., 1921. Vol. XVI, pp. 255-275. MO. WEATHER REV., Sept., 1921, 49: 481-488.

at our disposal. There are therefore 102 photometric readings in each series. In addition, with a clear sky the intensity of the total illumination from the sun and sky is measured on a horizontal surface, and on a surface normal to the direct solar rays, and the illumination from skylight alone is measured on these two surfaces and also on vertical surfaces facing 0° and 45° in azimuth from the sun. If the sky is cloudy the illumination is measured on a horizontal surface, and on vertical surfaces facing 0°, 45°, 90°, 135°, and 180° in azimuth from the sun. There are therefore 18 photometric readings (six sets of three readings each) in each series of illumination measurements. It is usually a matter of chance whether the readings are on azimuth circles to the right or to the left of the sun. Unless there is inequality in the cloud or haze distribution, or in the character of the earth's surface on the two sides of the sun's vertical, the sky brightness on the two sides should be symmetrical.

TABLE 1.—*Number of series of sky-brightness measurements.*

WASHINGTON, D. C.

Solar altitude.	0°	20°	40°	60°	70°	Total.
Clear sky	9	62	122	23	11	227
Thin clouds	2	34	36	16	......	88
Partly cloudy sky	1	21	57	24	17	120
Cloudy sky	6	30	26	21	4	87
Rain or snow	......	3	6	8	......	17
Total	18	150	247	92	32	539

CHICAGO, ILL., FEDERAL BUILDING.

Solar altitude.	0°	20°	26°	40°	60°	Total.
Clear sky	6	13	3	8	3	33
Thin clouds	......	8	5	2	6	21
Partly cloudy sky	5	9	......	7	9	30
Cloudy sky	4	6	3	1	1	15
Total	15	36	11	18	19	99

UNIVERSITY OF CHICAGO.

Solar altitude.	0°	20°	29°	40°	60°	Total.
Clear sky	2	11	3	9	10	35
Thin clouds	......	9	5	2	2	18
Partly cloudy sky	6	4	......	5	6	21
Cloudy sky	2	7	2	1	1	13
Total	10	31	10	17	19	87

The attempt is made to obtain complete series of sky-brightness and illumination measurements when the sun is 0°, 20°, 40°, 60°, and 70° above the horizon. On account of the length of the day the readings at 0° and 20° solar altitude are generally omitted in midsummer, and in winter the sun does not reach an altitude much in excess of 40°. In fact, at the Federal Building, Chicago, in January, the average altitude of the sun at the time of making the noon readings was 26°, and at the University of Chicago, at the end of January and early in February it was 29°. When rain was falling, only sky-brightness measurements up to an altitude of 60° could be made by pointing the photometer out of a window.

Table 1 gives the number of series of sky-brightness measurements obtained at Washington and Chicago with the sun at the altitudes indicated and with the different types of sky. In all there are about 55,000 photometric readings of sky brightness and 9,000 photometric readings of illumination intensity at Washington and 19,000 and 2,200, respectively, at Chicago.

In Tables 2 and 3 are summarized the sky-brightness measurements made at Washington and Chicago, respectively, during summer and winter months with a cloudless sky, and during winter months with the sun 20° above the horizon and the sky covered with clouds. It will be noted from Table 1 that at Chicago most of the sky-brightness measurements with a cloudy sky were obtained when the sun was at an altitude of 20°.

TABLE 2.—*Averages of sky-brightness measurements expressed in terms of zenith brightness. Washington, D. C.*

Solar altitude.	Point in sky where brightness was measured.								Zenith brightness.
	Azimuth from sun.	Altitude.							
		2°	15°	30°	45°	60°	75°	90°	*ml.*
	CLEAR SKY, WINTER.								
0°	0	12.66	9.61	4.33	2.40	1.44	1.15	1.00	27.1
	45	4.40	4.76	2.83	1.98	1.36	1.15		
	90	2.43	2.76	2.08	1.47	1.20	1.10		
	135	2.99	3.43	2.41	1.58	1.17	1.03		
	180	3.83	4.20	2.74	1.77	1.25	1.08		
20°	0	23.52	......	9.78	4.27	2.26	1.42	1.00	281
	45	8.91	5.54	3.76	2.57	1.75	1.27		
	90	3.95	2.60	1.69	1.30	1.10	1.06		
	135	3.92	2.34	1.42	1.01	0.87	0.88		
	180	4.38	2.55	1.42	0.99	0.81	0.79		
40°	0	8.29	6.81	9.44	......	2.72	1.53	1.00	544
	45	4.56	3.45	2.77	2.21	1.76	1.36		
	90	2.62	1.66	1.12	1.00	0.89	0.95		
	135	2.51	1.33	0.82	0.68	0.66	0.75		
	180	2.76	1.44	0.81	0.60	0.58	0.69		
	CLEAR SKY, SUMMER.								
20°	0	21.10	......	10.85	4.06	2.34	1.40	1.00	400
	45	7.72	5.90	3.91	2.74	1.94	1.31		
	90	3.42	2.81	1.78	1.35	1.07	1.14		
	135	2.48	1.86	1.23	0.83	0.72	0.82		
	180	2.85	2.13	1.19	0.85	0.74	0.76		
40°	0	7.35	6.19	8.43	......	2.75	1.58	1.00	803
	45	4.15	3.13	2.69	2.45	1.88	1.42		
	90	2.13	1.41	1.13	0.97	0.99	1.04		
	135	1.74	1.13	0.74	0.60	0.62	0.74		
	180	1.83	1.11	0.68	0.54	0.53	0.68		
60°	0	2.08	1.74	1.84	2.51	......	1.65	1.00	1,650
	45	1.74	1.53	1.30	1.53	1.67	1.41		
	90	1.16	0.88	0.72	0.74	0.88	0.99		
	135	0.95	0.61	0.47	0.50	0.58	0.75		
	180	1.00	0.64	0.47	0.50	0.54	0.72		
70°	0	1.45	1.29	1.13	1.60	3.30	......	1.00	2,300
	45	1.25	0.90	0.89	1.07	1.33	1.53		
	90	0.77	0.65	0.56	0.54	0.62	0.89		
	135	0.62	0.42	0.37	0.38	0.44	0.66		
	180	0.58	0.39	0.31	0.31	0.41	0.61		
	CLOUDY SKY, WINTER.								
20°	0	0.39	0.59	0.80	0.93	1.03	1.04	1.00	989
	45	0.40	0.55	0.67	0.84	0.97	0.97		
	90	0.31	0.56	0.68	0.81	0.90	0.92	Max.=2,211	
	135	0.31	0.49	0.66	0.80	0.86	0.94		
	180	0.32	0.54	0.67	0.83	0.94	0.98	Min.=245	

TABLE 3.—*Average of sky-brightness measurements expressed in terms of zenith brightness. Chicago, Ill.*

Place.	Solar altitude.	Point in sky where brightness was measured.								Zenith brightness.
		Azimuth from sun.	Altitude.							
			2°	15°	30°	45°	60°	75°	90°	*ml.*
CLEAR SKY, WINTER.										
University	0°	0	9.80	8.04	3.67	2.03	1.38	1.08	1.00	19.4
		45	3.04	4.06	2.14	1.50	1.13	0.87		
		90	1.03	2.36	1.79	1.46	1.29	1.07		
		135	1.31	2.46	1.84	1.47	1.18	0.78		
		180	0.80	2.84	3.34	1.64	1.22	0.96		
Federal Building	0°	0	1.80	4.41	4.00	1.21	1.48	1.13	1.00	19.7
		45	0.85	2.11	2.04	1.54	1.36	1.10		
		90	0.80	1.29	1.27	1.24	1.03	0.99		
		135	0.88	1.88	1.00	1.43	1.05	1.08		
		180	1.11	2.12	1.85	1.66	1.25	1.09		
University	20°	0	16.38	......	9.18	4.25	2.21	1.22	1.00	345
		45	6.38	5.00	3.59	2.58	1.93	1.33		
		90	2.51	2.22	1.59	1.30	1.40	1.05		
		135	2.06	1.50	1.25	0.98	0.95	0.85		
		180	2.03	1.75	1.14	0.89	0.72	0.77		
Federal Building	20°	0	13.56	......	9.86	4.37	2.34	1.55	1.00	340
		45	5.30	4.87	3.37	2.59	1.96	1.16		
		90	1.98	1.93	1.70	1.35	1.31	1.00		
		135	1.24	1.27	1.01	0.75	0.66	0.72		
		180	1.32	1.45	1.08	0.79	0.72	0.82		
University	29°	0	13.65	18.80	......	3.72	2.61	1.37	1.00	433
		45	5.32	4.11	3.50	2.59	1.92	1.32		
		90	2.59	1.96	1.49	1.07	1.02	1.03		
		135	1.89	1.65	1.01	0.82	0.71	0.78		
		180	2.13	1.78	1.05	0.82	0.77	0.71		
Federal Building	26°	0	7.81	15.73	12.14	4.96	2.44	1.46	1.00	511
		45	3.84	4.12	4.02	2.85	2.04	0.94		
		90	0.95	1.20	1.39	0.93	0.79	1.00		
		135	0.73	0.72	0.73	0.73	0.73	0.89		
		180	0.65	0.80	0.70	0.58	0.63	0.75		
CLOUDY SKY, WINTER.										
University	20°	0	0.29	0.52	0.86	1.06	1.07	1.08	1.00	614
		45	0.30	0.47	0.73	0.89	0.96	0.99		
		90	0.29	0.41	0.63	0.86	0.91	0.97	Max.=1,074	
		135	0.30	0.42	0.58	0.71	0.86	0.88		
		180	0.25	0.37	0.56	0.73	0.94	0.91	Min.=84	
Federal Building	20°	0	0.38	0.56	0.83	1.02	1.23	1.30	1.00	500
		45	0.33	0.61	0.56	0.78	0.93	1.10		
		90	0.42	0.64	0.74	0.92	1.09	1.10	Max.=1,034	
		135	0.34	0.43	0.60	0.98	1.13	1.08		
		180	0.33	0.56	0.80	0.84	0.70	0.93	Min.=132	
CLEAR SKY, SUMMER.										
University	8°	0	12.29	......	5.64	2.37	1.18	1.19	1.00	231
		45	5.46	5.09	2.65	1.83	1.17	0.90		
		90	3.43	2.37	1.35	1.07	0.95	0.76		
		135	2.62	2.18	1.36	0.96	0.72	0.84		
		180	2.73	2.69	1.64	0.91	0.79	0.86		
Do	20°	0	14.35	......	11.44	5.07	2.71	1.62	1.00	528
		45	5.91	5.04	3.88	2.62	1.86	1.32		
		90	2.77	2.26	1.61	1.25	1.09	1.04		
		135	1.69	1.60	1.04	0.73	0.68	0.72		
		180	1.58	1.78	1.04	0.71	0.64	0.70		
Federal Building	20°	0	15.08	13.73	13.58	6.19	2.79	2.20	1.00	419
		45	4.76	4.81	4.54	3.27	1.97	1.37		
		90	1.65	1.56	1.32	1.06	0.91	0.90		
		135	1.50	1.51	0.91	0.73	0.71	0.80		
		180	1.20	1.13	0.76	0.54	0.55	0.59		
University	40°	0	6.29	5.67	7.28	......	2.66	1.63	1.00	810
		45	3.72	3.07	2.70	2.57	2.16	1.49		
		90	1.68	1.41	1.15	1.09	0.96	0.98		
		135	1.73	1.05	0.77	0.73	0.72	0.83		
		180	1.26	0.97	0.61	0.48	0.50	0.62		
Federal Building	40°	0	4.50	5.56	6.35	......	3.23	1.76	1.00	900
		45	1.51	3.09	3.38	2.69	2.17	1.37		
		90	1.16	1.19	0.99	......	0.95	......		
		135	0.67	0.57	0.49	0.43	0.49	0.70		
		180	0.97	0.78	0.51	0.41	0.47	0.68		
University	60°	0	1.75	1.88	2.06	2.44	......	1.67	1.00	1920
		45	1.32	1.23	1.25	1.38	1.52	1.30		
		90	0.84	0.72	0.64	0.82	0.88	0.88		
		135	0.80	0.69	0.52	0.52	0.63	0.82		
		180	0.65	0.55	0.45	0.50	0.50	0.66		
Federal Building	60°	0	1.63	1.88	2.19	3.24	......	1.83	1.00	1360
		45	1.36	1.33	1.11	1.54	1.36	1.40		
		90	0.94	0.67	0.61	0.58	0.72	1.09		
		135	0.96	0.69	0.56	......	0.63	......		
		180	1.00	0.63	0.39	0.38	0.43	0.60		

Referring again to Figure 1, the irregularly curved lines are lines of equal brightness that have been drawn to represent the brightness of the sky at Washington on the morning of February 17, 1922, with the sun at an altitude of 20°, and the ground covered with newly fallen crusted snow. The figures on the left above the sun represent the brightness of the sky with reference to the zenith brightness; the figures on the right and at the bottom of the figure, the brightness of the sky in millilamberts. The sky 90° from the sun and in his vertical was a deep blue and unusually dark. Near the horizon it was unusually bright on account of the reflection of light to the atmosphere from the snow surface, and especially beyond 90° in azimuth from the sun.

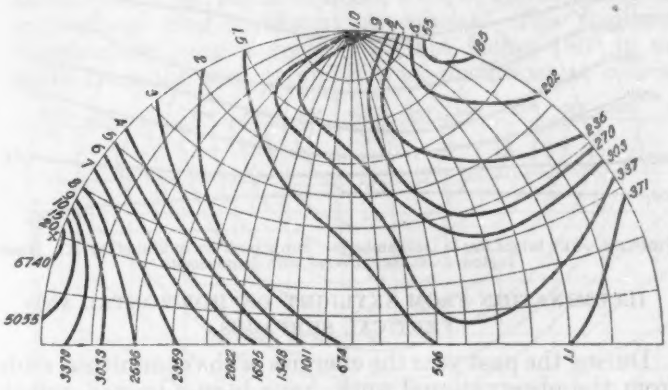


FIGURE 2.—Sky brightness in millilamberts. Sun's position indicated by X. Federal Building, Chicago, Ill., cloudless sky with dense smoke.

Figure 2 shows the brightness of the sky as measured from the top of the dome on the Federal Building, Chicago, Ill., on the morning of January 16, 1922, with no clouds in the sky, but heavy smoke in the lower atmosphere. The sun was at altitude 20°, and the ground was covered with snow, as was the case at Washington on February 17, but the snow was not clean. Compared with Figure 1, Figure 2 gives a brighter zenith, a point of minimum that is less bright, and a horizon beyond azimuth 90° from the sun only about one-fourth as bright.

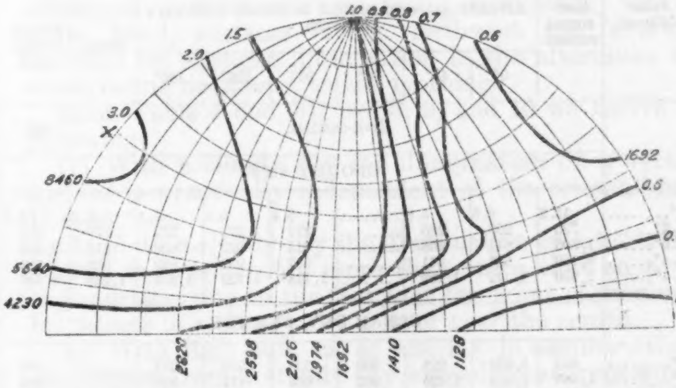


FIGURE 3.—Sky brightness in millilamberts. Sun's position indicated by X. Washington, D. C., sky covered with dense haze.

Figure 3 represents the sky brightness at Washington on the morning of July 5, 1921, with the sky covered with dense haze, but without clouds, and the sun 40° above the horizon. The sky is much brighter than a clear blue sky, except near the horizon opposite the sun.

Figure 4 represents the mean of all the sky-brightness measurements at Washington with the sun 40° above the horizon, and the clouds so dense that neither blue sky nor the sun could be seen. The brightest point is near the zenith, and there is little variation in brightness with azimuth. The zenith and in general the sky opposite the sun is brighter when covered with clouds than when clear, but near the horizon and in the vicinity of the sun the clear sky is much the brighter. Thin clouds, and clouds that partly cover the sky, increase its brightness much the same as does haze.

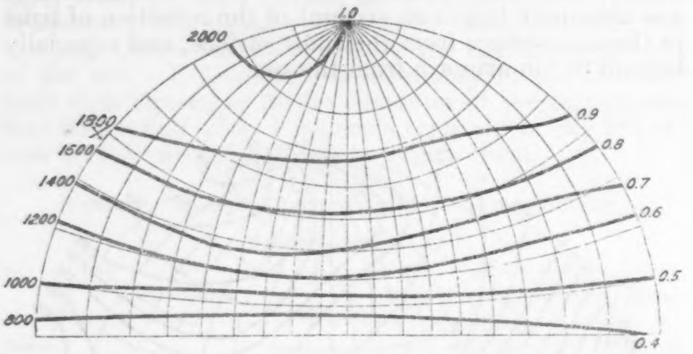


FIGURE 4.—Sky brightness in millilamberts. Sun's position indicated by X. Washington, D. C., sky covered with dense clouds.

ILLUMINATION FROM SKYLIGHT ON HORIZONTAL AND VERTICAL SURFACES.

During the past year the energies of the committee, aside from the observational work, have been directed principally to computing from the clear-sky-brightness measurements, as summarized in Tables 2 and 3, the resulting illumination on vertical surfaces facing in azimuth 70°, 90°, 135°, and 180° from the sun. The process is a simple one. As explained in the 1921 report,[8] the sky is divided into zones of equal angular width about a point on the horizon 90° in azimuth from the illuminated surface, and the horizontal component of the illumination from each zone is determined. The sum of the illumination from all the zones gives the total skylight illumination on the vertical surface.

TABLE 4.—*Illumination from skylight, Washington, D. C.*

Solar altitude.	On horizontal surface.	On vertical surface. Azimuth between normal to surface and sun's azimuth. 0°	45°	70°	90°	135°	180°	Mean.	Zenith brightness.
	Foot-candles.								Ml.
	CLOUDY SKY.								
0°	15.2	5.6	5.8	....	6.4	6.7	7.1	6.3	15.8
20.2°	726	298	280	....	273	273	272	279	989
41.0°	1,505	614	608	....	615	622	606	613	2,000
61.4°	2,150	881	941	....	977	932	929	932	3,600
71.4°	2,950	1,142	1,103	....	1,118	1,122	1,203	1,138	4,840
	CLEAR SKY, SUMMER.								
20°	840	1,252	1,028	803	526	316	293	....	400
40°	1,340	1,454	1,325	932	686	417	358	....	803
60°	1,600	1,420	1,255	923	751	559	486	....	1,650
70°	1,600	1,291	1,074	903	754	542	475	....	2,300
	CLEAR SKY, WINTER.								
0°	67.8	64.6	63.7	....	36.6	30.2	31.5	....	27.1
20°	683	1,042	873	562	393	265	257	....	281
40°	977	1,121	936	690	505	325	295	....	544

[8] Trans. Illum. Engrg. Soc., vol. 16: 267; MO. WEATHER REV., Sept., 1921, 49: 485.

Table 4 summarizes the results of these computations from Washington measurements, and also the illumination measurements, for both clear and cloudy skies. The cloudy-sky measurements have been confined to skies with so dense a cloud layer that the position of the sun could not be seen. No seasonal variation in the illumination intensity is apparent. With clear skies the computations have been made for both midsummer (June to August) and midwinter (December to February) conditions.

These data have been plotted on Figure 5 (summer conditions) and Figure 6 (winter conditions) with the solar altitude as abscissas and illumination intensities as ordinates. By interpolating between the curves it is possible to determine the illumination intensity for both summer and winter conditions on a vertical surface

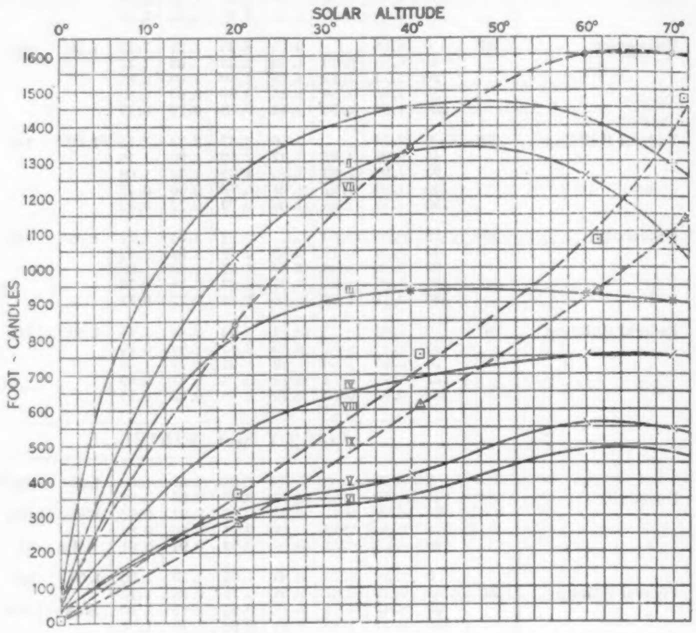


FIGURE 5.—Curves of summer skylight illumination intensity on different surfaces.
Curve I. Clear sky. Vertical surface facing 0° in azimuth from sun.
Curve II. Clear sky. Vertical surface facing 45° in azimuth from sun.
Curve III. Clear sky. Vertical surface facing 70° in azimuth from sun.
Curve IV. Clear sky. Vertical surface facing 90° in azimuth from sun.
Curve V. Clear sky. Vertical surface facing 135° in azimuth from sun.
Curve VI. Clear sky. Vertical surface facing 180° in azimuth from sun.
Curve VII. Clear sky. Horizontal surface.
Curve VIII. Cloudy sky. Horizontal surface. (Note: Double the intensity scale.)
Curve IX. Cloudy sky. Vertical surface.

facing at any desired azimuth from the sun, and with the sun at any desired altitude. For spring and fall months a straight-line interpolation has been made between winter and summer values.

Measurements with the sun on the horizon were made during the winter months only, and these measurements have been used for summer as well. With the sun at altitudes 20° and 40° it will be noted that the zenith brightness in winter is approximately 70 per cent of the corresponding brightness in summer. The percentage of winter to summer illumination is somewhat greater than this, since the brightness of the sky near the horizon in terms of the zenith brightness is greater in winter than in summer.

In the MONTHLY WEATHER REVIEW for November, 1919, 47: 770–771, are given the altitude and azimuth of the sun for the 21st day of each month and for even-hour angles of the sun from the meridian, for latitudes 30°, 36°, 42°, and 48° north. Using the azimuths and altitudes for latitude 42° N., in connection with the

illumination intensity curves of Figures 5 and 6, Figures 7 to 18 have been drawn. Latitude 42° N. was selected because many important industrial districts are near this

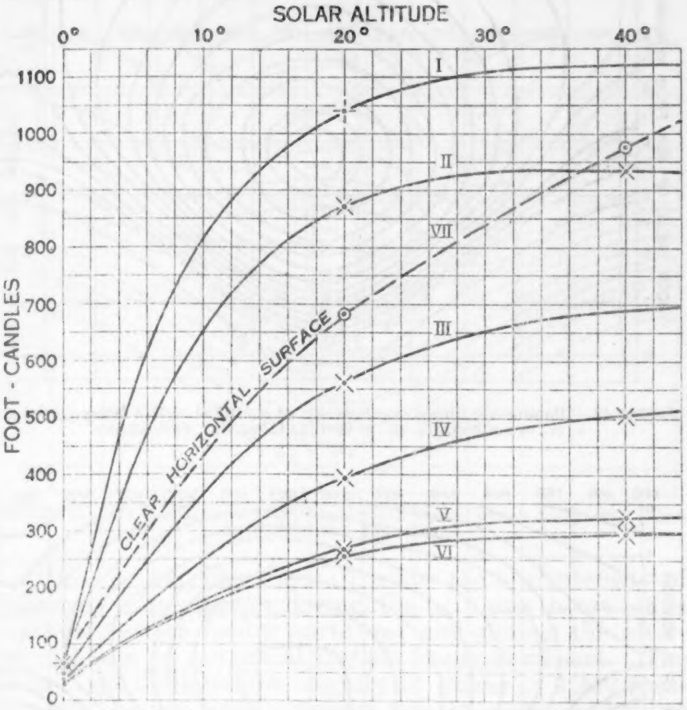


FIGURE 6.—Curves of winter skylight illumination intensity on different surfaces.
Curve I. Clear sky. Vertical surface facing 0° in azimuth from sun.
Curve II. Clear sky. Vertical surface facing 45° in azimuth from sun.
Curve III. Clear sky. Vertical surface facing 70° in azimuth from sun.
Curve IV. Clear sky. Vertical surface facing 90° in azimuth from sun.
Curve V. Clear sky. Vertical surface facing 135° in azimuth from sun.
Curve VI. Clear sky. Vertical surface facing 180° in azimuth from sun.
Curve VII. Clear sky. Horizontal surface.

latitude, and also because measurements made at Washington, latitude 38° 56′ N., and Chicago, Ill., latitude 41° 53′ N., represent fairly well the sky brightness at this latitude east of the Mississippi River. Farther west the clear sky is generally a deeper blue and not so bright. Probably clear skies average brighter in low

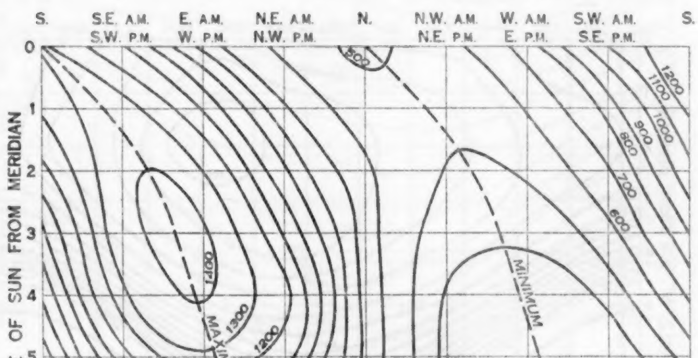


FIGURE 7.—Variations in skylight illumination on vertical surfaces differently oriented at latitude 42° north on July 21. Cloudless sky. Foot-candles.

than in high latitudes, especially in winter. This conclusion is supported by Little's measurements made near Key West, Fla., in February, 1918, which give for the zenith sky brightness with the sun at altitudes averaging 22.8°, 42.0°, and 53°, 390, 780, and 1,150 millilamberts, respectively; while measurements made by him from a ship off Long Island, N. Y., in October, 1917, give for the sky brightness with solar altitudes averaging 20.8°, and 41.2°, 296 and 495 millilamberts, respectively. The latter are somewhat lower readings than those obtained at Washington in winter with similar solar altitudes, while the Key West measurements are considerably higher.

Figure 7 shows the variations with the hour of the day in skylight illumination on vertical surfaces, such as the walls of buildings, differently oriented, on July 21, at latitude 42° N. with a clear sky. The maximum illumination is, of course, on a vertical surface facing the sun. It faces about east-northeast at sunrise, east at about 7:30 a. m., south at noon, west at about 4:30 p. m., and about west-northwest at sunset. The minimum illumination is on a vertical surface facing 180° in azimuth from the sun, or about west-southwest at sunrise,

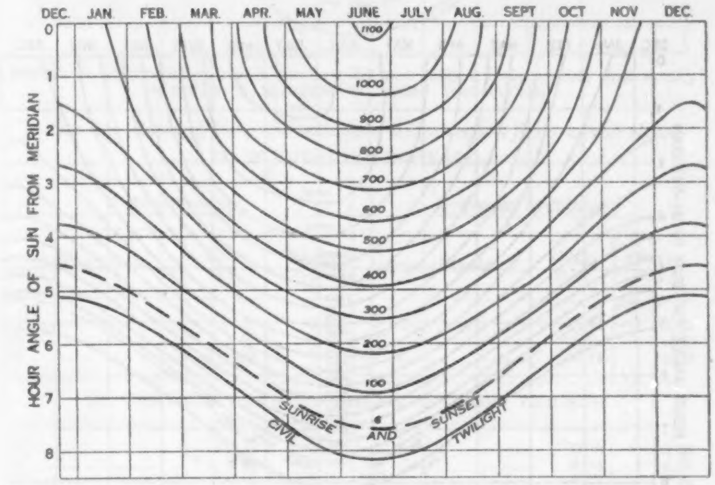


FIGURE 8.—Illumination from a cloudy sky on a vertical surface at latitude 42° north. Foot-candles.

west at about 7:30 a. m., north at noon, east at about 4:30 p. m., and about east-southeast at sunset. Taking into consideration the hours between 7 a. m. and 5 p. m., which cover the usual working day, in the morning vertical surfaces facing northwest are most unfavorably oriented for illumination from a clear sky, and in the afternoon vertical surfaces facing northeast. On the other hand, surfaces facing northwest are favorably oriented for skylight illumination in the afternoon, and those facing northeast, in the morning.

From Table 4 and Figures 8, 9, and 10 we derive the following:

(1) With a cloudy sky the illumination on a vertical surface is practically independent of the orientation of that surface.

(2) With a cloudy sky the illumination on a horizontal surface is considerably more than twice that on a vertical surface, due to the fact that the point of maximum brightness of a cloudy sky is in or near the zenith.

(3) With high sun, as at midday in summer, the illumination from a cloudy sky exceeds that from a clear sky except on vertical surfaces facing the sun. This is not true with low sun, however.

The eight figures, 11 to 18, inclusive, give the illumination from clear skies on vertical surfaces oriented as indicated. Were it not for the fact that clear skies in July, August, September, October, and November, are on the average whiter and therefore brighter than clear

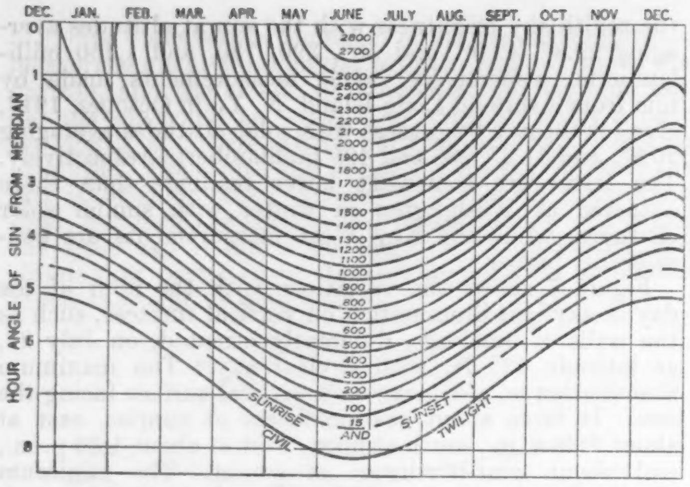


FIGURE 9.—Illumination from a cloudy sky on a horizontal surface at latitude 42° north. Foot-candles.

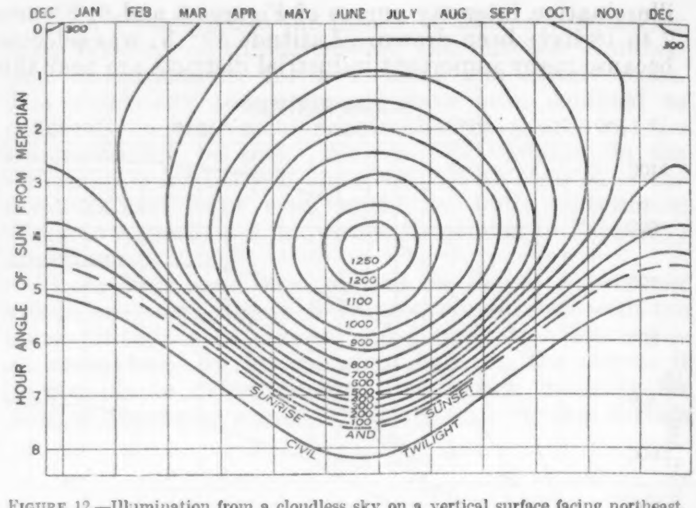


FIGURE 12.—Illumination from a cloudless sky on a vertical surface facing northeast, a. m., or northwest, p. m., at latitude 42° north. Foot-candles.

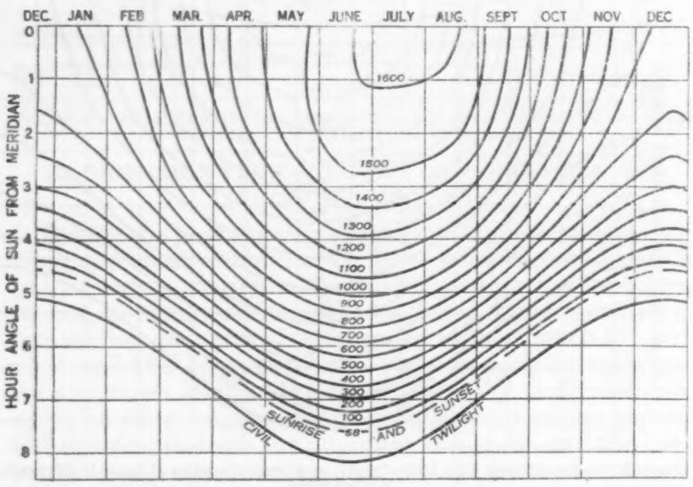


FIGURE 10.—Illumination from a cloudless sky on a horizontal surface at latitude 42° north. Foot-candles.

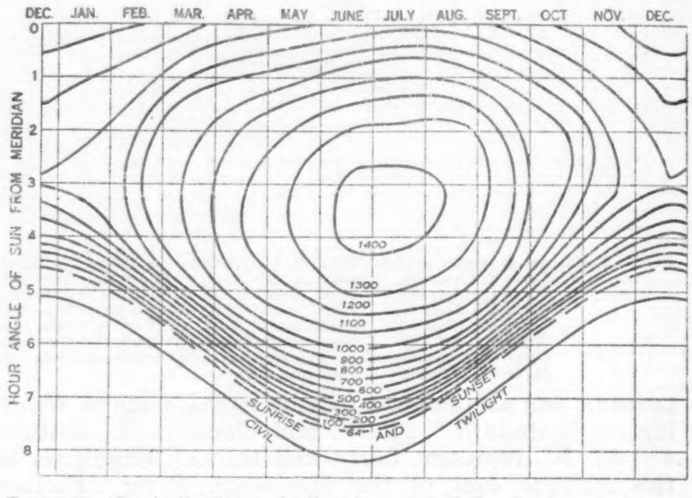


FIGURE 13.—Illumination from a cloudless sky on a vertical surface facing east, a. m., or west, p. m., at latitude 42° north. Foot-candles.

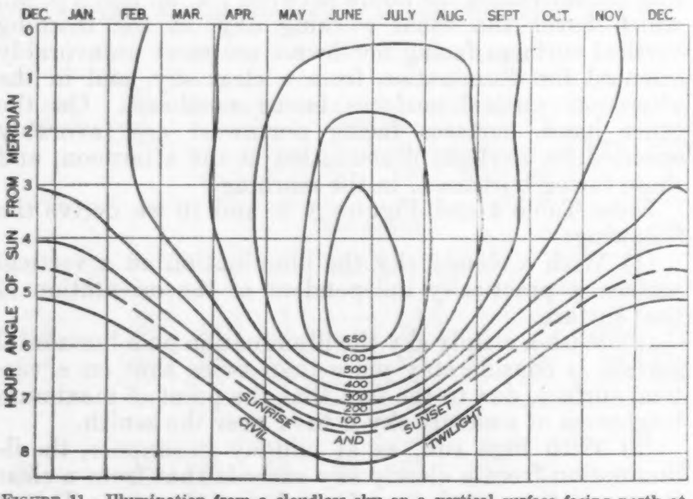


FIGURE 11.—Illumination from a cloudless sky on a vertical surface facing north at latitude 42° north. Foot-candles.

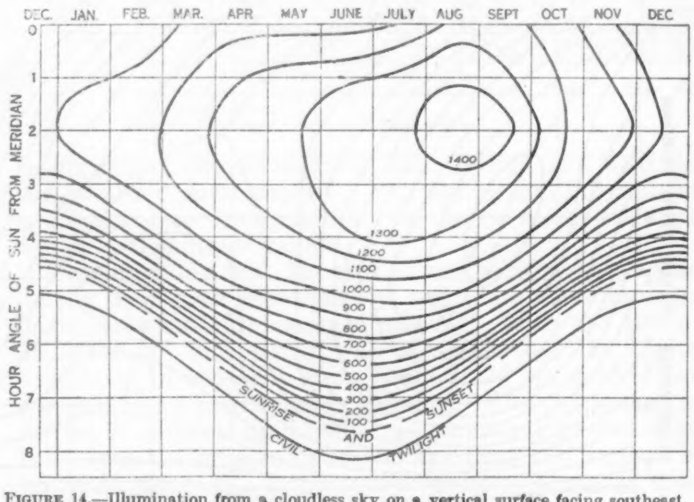


FIGURE 14.—Illumination from a cloudless sky on a vertical surface facing southeast, a. m., or southwest, p. m., at latitude 42° north. Foot-candles.

skies in May, April, March, February, and January, respectively, the lines of equal illumination intensity would be nearly symmetrical on each side of a vertical line representing June 21.

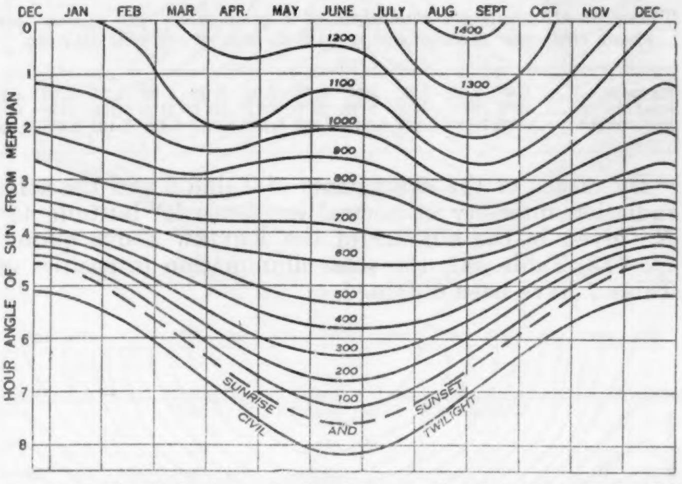


FIGURE 15.—Illumination from a cloudless sky on a vertical surface facing south at latitude 42° north. Foot-candles.

These figures, like Figure 7, show the low intensity of clear-sky illumination during the morning hours on a vertical surface facing northwest and during the afternoon hours on a vertical surface facing northeast. The maximum illumination, slightly in excess of 1,400 foot-candles, occurs late in August and in early September at midday, on a vertical surface facing south; from the end of July to the latter part of September, on a vertical surface facing southeast at 10 a. m., and southwest at 2 p. m.; and from early in June to the middle of August, on a vertical surface facing east at 8:30 a. m. and west at 3:30 p. m. Illumination on a vertical surface facing north is good throughout the day in summer but poor in winter.

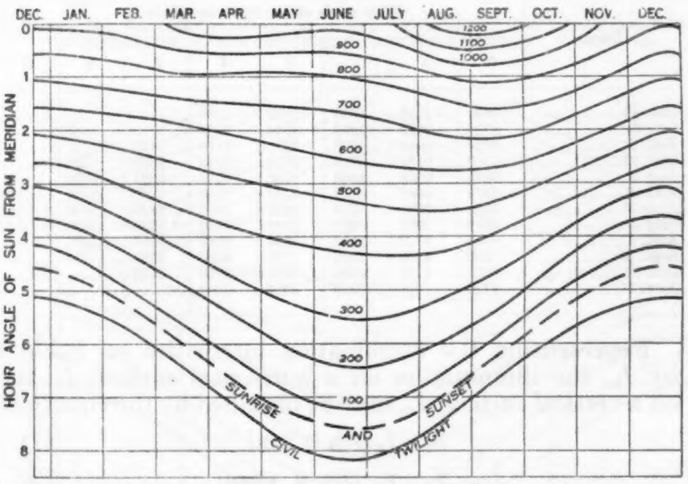


FIGURE 16.—Illumination from a cloudless sky on a vertical surface facing southwest, a. m., or southeast, p. m., at latitude 42° north. Foot-candles.

In the report for 1921[4] it was shown that at the Federal Building, Chicago, which is in the smoky Loop District, the illumination on a vertical surface facing 180° from the sun is only about two-thirds as intense as at Washington, while at the University of Chicago the sky-brightness and the illumination measurements differ but little from the corresponding Washington measurements.

[4] MO. WEATHER REV., Sept., 1921, *49:* 482 and 486.

Table 5 gives a summary of comparisons between Washington and Chicago illumination measurements on a horizontal surface, and on a vertical surface facing 180° from the sun, under winter conditions.

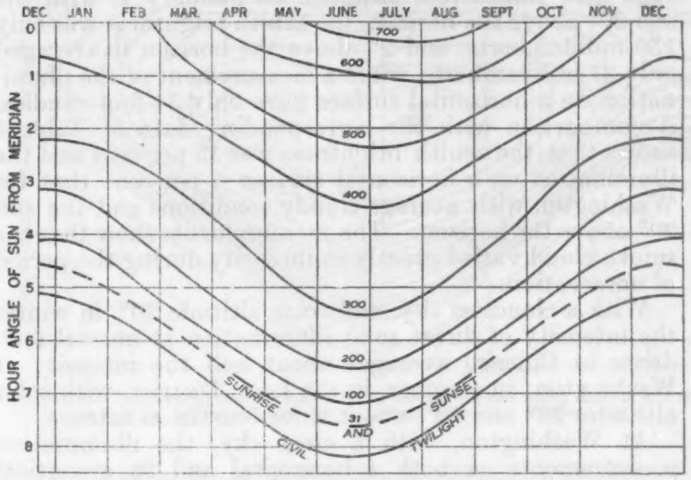


FIGURE 17.—Illumination from a cloudless sky on a vertical surface facing west, a. m., or east, p. m., at latitude 42° north. Foot-candles.

TABLE 5.—*Ratio, Chicago/Washington illumination from winter skies.*

ON HORIZONTAL SURFACE.

Federal Building.			University of Chicago.		
Solar altitude.	Clear sky.	Cloudy sky.	Solar altitude.	Clear sky.	Cloudy sky.
0°	0.49	0.90	0°	0.48	0.69
20°	1.05	0.77	20°	1.03	0.56
26°	0.84	0.82	29°	1.14	0.76

ON VERTICAL SURFACE FACING 180° FROM THE SUN.

Solar altitude.	Clear sky.	Cloudy sky.	Solar altitude.	Clear sky.	Cloudy sky.
0°	0.42	0.85	0°	0.46	0.55
20°	0.69	0.54	20°	0.84	0.56
26°	0.62	0.88	29°	0.97	0 98

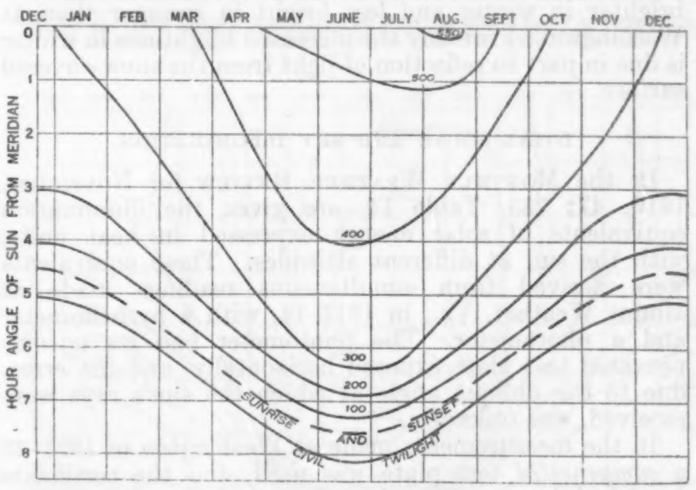


FIGURE 18.—Illumination from a cloudless sky on a vertical surface facing northwest, a. m., or northeast, p. m., at latitude 42° north. Foot-candles.

The darkening effect of the smoke is rather more pronounced in winter than in summer on a vertical surface facing away from the sun. The effect is slight at both seasons of the year on surfaces facing the sun when no clouds are present, except when the sun is near the horizon. The effect is closely related to the velocity of the wind. With light wind, and especially when the sky is covered with clouds, the smoke sometimes forms a

cover or blanket of great thickness which cuts off practically all the daylight. A dark day results, and artificial lighting is necessary outdoors as well as in. No such days are included in the sky-brightness measurements for Chicago here considered, although on January 4, with the sun 20° above the horizon, the zenith brightness was only 150 millilamberts, and 2° above the horizon it averaged only 37 millilamberts, while a measurement of the illumination on a horizontal surface gave only 34-foot-candles. A comparison with the corresponding data of Table 4 shows that the zenith brightness was 15 per cent and the illumination on a horizontal surface 5 per cent that for Washington with average cloudy conditions and the sun 20° above the horizon. The measurements show that the smoke cloud varied greatly in intensity during the period of observation.

With a cloudless sky, and solar altitude 20°, in winter the intensity of direct solar illumination at normal incidence at Chicago averages about half the intensity at Washington; in summer, in the Loop District, with solar altitudes 20° and 40°, about three-fourths as intense.

At Washington, with a clear sky, the illumination measurements on both a horizontal and on a vertical surface vary between 150 per cent and 60 per cent of the values given in Table 4. With a cloudy sky the variation is between 200 and 30 per cent. When rain is falling, the illumination is about half as great as the average for cloudy skies; with a sky partly covered with clouds, the illumination on a horizontal surface may be from three to four times as intense, and on a vertical surface two to three times as intense, as the corresponding illumination from a clear sky given in Table 4.

From seasonal averages of sky brightness for Davos Platz, Switzerland, given by Dorno,[5] it appears that when expressed in terms of the zenith brightness the sky at Davos Platz opposite the sun is brighter than at Washington. The zenith brightness in winter averages more than 50 per cent brighter, and in summer a few per cent less bright at Davos Platz than at Washington. On the whole, Davos Platz skies when free from clouds are brighter in winter and less bright in summer than at Washington. Probably the increased brightness in winter is due in part to reflection of light from the snow-covered surface.

TOTAL SOLAR AND SKY ILLUMINATION.

In the MONTHLY WEATHER REVIEW for November, 1919, **47**; 785, Table 14, are given the illumination equivalents of solar energy expressed in heat units, with the sun at different altitudes. These equivalents were derived from simultaneous readings made at Mount Weather, Va., in 1913–14, with a pyrheliometer and a photometer. The photometer had its uncompensated test plate exposed horizontally, and the error, due to the oblique angle at which the sun's rays were received, was unknown.

In the measurements made at Washington in 1921–22 a *compensated* test plate was used, and the certificate furnished by the Electrical Testing Laboratories, New York, shows no appreciable error due to an obliquity in the angle of incidence of the sun's rays. Illumination intensities were measured with the test plate horizontal and also normal to the incident solar rays, but the latter measurements were given twice the weight of the former. Comparison of these measurements with simultaneous pyrheliometric measurements give the illumination equivalents of Table 6. These are considerably higher than the equivalents determined at Mount Weather, and particularly with low sun, as one would expect.

[5] Dorno, C. Himmelshelligkeit, Himmelspolarisation und Sonnenintensität in Davos 1911 bis 1918. Veröffentlichungen des Preussischen Meteorologischen Instituts., Nr. 303 Abhandlungen Bd. VI, Tabellen 4A und 6.

TABLE 6.—*Illumination equivalent of 1 gram-calory per minute per square centimeter of solar energy with the sun at different altitudes.*

Air mass	1.06	1.10	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50
Solar altitude	70°0	65°0	42°7	30°0	23°5	19°3	16°4	14°3	12°6	11°3	10°2
Foot-candles	7,040	7,020	6,880	6,740	6,650	6,580	6,520	6,460	6,410	6,370	6,320

By means of the equivalents of Table 6 and the solar radiation intensity at normal incidence for latitude 42° N., given in the number of the REVIEW above quoted (p. 773, Table 5a), the solar illumination intensities of Table 7 have been obtained.

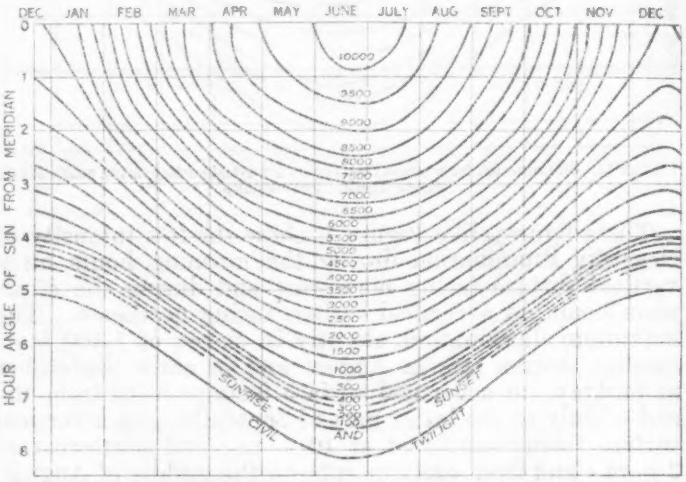


FIGURE 19.—Total daylight illumination on a horizontal surface with a cloudless sky at latitude 42° north. Foot-candles.

TABLE 7.—*Solar illumination intensity at normal incidence at latitude 42° north, with a cloudless sky (east of the Mississippi River).*

Day.	Hour angle of sun from meridian.							
	0	1	2	3	4	5	6	7
Dec. 21	7600	7300	6640	5190	2460	....	....	....
Jan. 21	8120	7890	7290	6040	3760	....	....	....
Feb. 21	9140	9040	8440	7450	6140	2460	....	....
Mar. 21	9270	9110	8710	7910	6700	4650	720	....
Apr. 21	9230	9060	8800	8300	7350	5860	3600	....
May 21	9070	8990	8630	8140	7480	6260	4700	1200
June 21	9080	9000	8740	8220	7430	6420	4880	2160
July 21	9070	8990	8670	8140	7550	6330	4830	1200
Aug. 21	8810	8710	8390	7830	6880	5460	2990	....
Sept. 21	8910	8760	8510	7710	6500	4590	720	....
Oct. 21	8510	8420	7960	6910	5220	2100	....	....
Nov. 21	8120	7890	7290	5960	3390	....	....	....

Representing the illumination intensities of Table 7 by I_n, the illumination on a horizontal surface, I_h, and on a vertical surface, I_v, may be obtained by the equations

$$I_h = I_n \sin a \text{ and} \qquad (1)$$

$$I_v = I_n \cos a \cos \alpha \qquad (2)$$

where a is the altitude of the sun, and α is the difference between the sun's azimuth and the azimuth of a line normal to the vertical surface. The surface will be illuminated by the sun only when the value of α is less than 90°.

Adding the values of I_h to the skylight-illumination values for corresponding days and hours given on figure 10, we obtain the total daylight illumination on a horizontal surface for a cloudless sky of average brightness at latitude 42° N., which is charted on Figure 19.

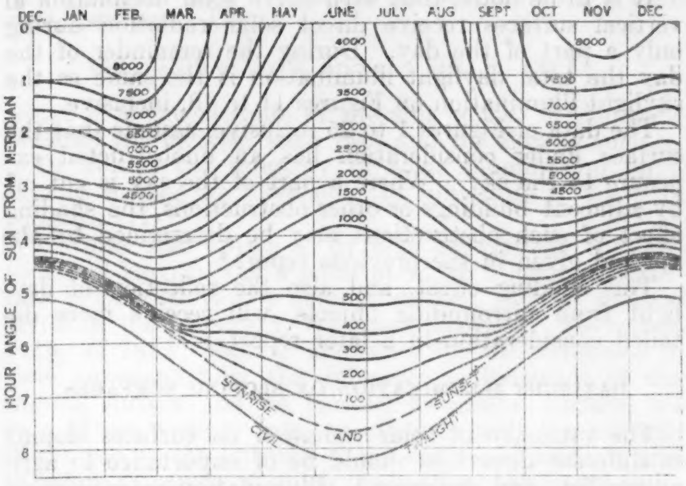


FIGURE 20.—Total daylight illumination on a vertical surface facing south with a cloudless sky at latitude 42° north. Foot-candles.

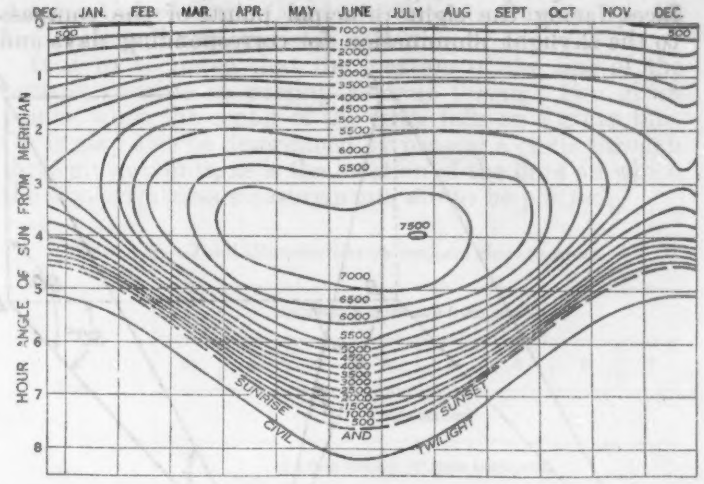


FIGURE 23.—Total daylight illumination on a vertical surface facing east, a. m., or west, p. m., with a cloudless sky at latitude 42° north. Foot-candles.

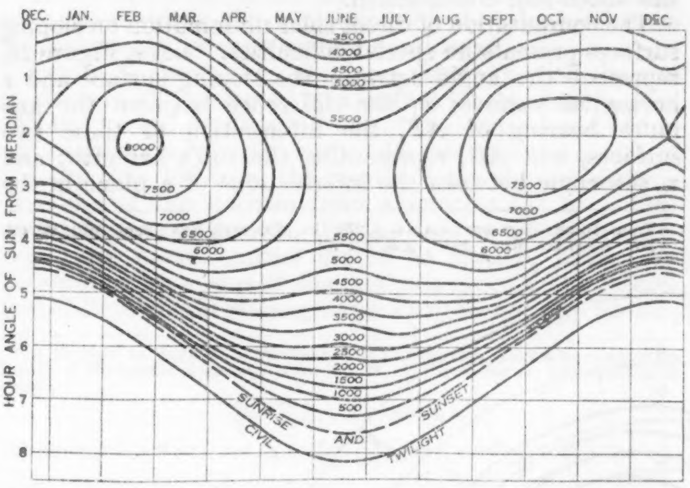


FIGURE 21.—Total daylight illumination on a vertical surface facing southeast, a. m., or southwest, p. m. with a cloudless sky at latitude 42° north. Foot-candles.

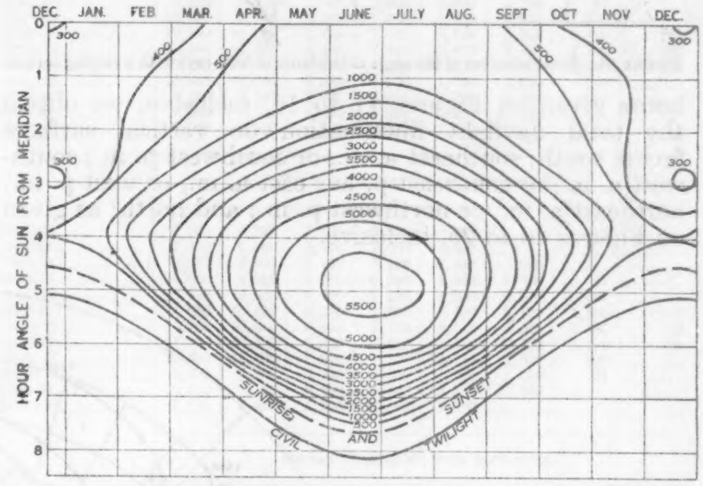


FIGURE 24.—Total daylight illumination on a vertical surface facing northeast, a. m., or northwest, p. m., with a cloudless sky at latitude 42° north. Foot-candles.

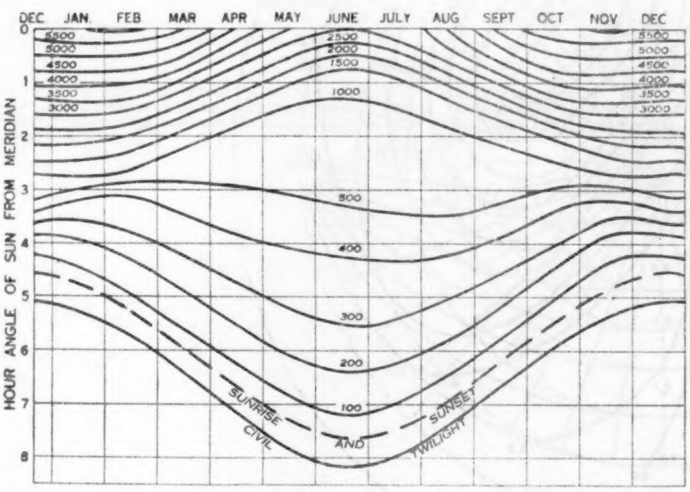


FIGURE 22.—Total daylight illumination on a vertical surface facing southwest, a. m., or southeast, p. m., with a cloudless sky at latitude 42° north. Foot-candles.

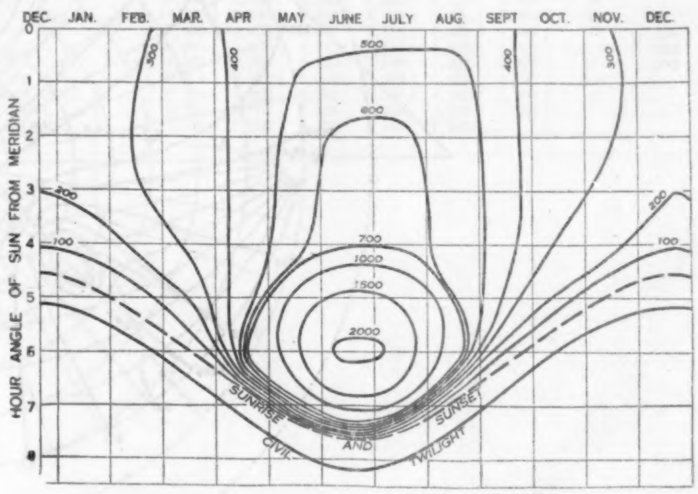


FIGURE 25.—Total daylight illumination on a vertical surface facing north with a cloudless sky at latitude 42° north. Foot-candles.

Similarly, by adding the values of I_v for vertical surfaces facing the eight principal points of the compass to the skylight illumination for corresponding days and

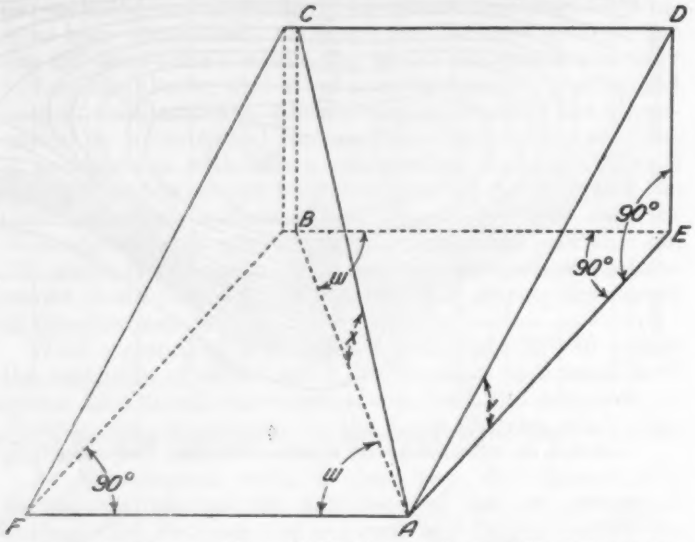


FIGURE 26.—Determination of the angle of incidence of solar rays with a sloping surface.

hours given on Figures 11 to 16, inclusive, we obtain the total daylight illumination on vertical surfaces facing south; southeast a. m., or southwest p. m.; southwest a. m., or southeast p. m.; east a. m., or west p. m.; northeast a. m., or northwest p. m.; and north; as given on Figures 20 to 25, inclusive.

It is to be noted that with north solar declination al vertical surfaces receive direct solar radiation during only a part of the day. During the remainder of the day the total daylight illumination is the same as the skylight illumination on Figures 11 to 18, inclusive.

The data of Figures 1 to 25 inclusive, assume that the surface under consideration has an unobstructed exposure to the sky. Where a part of the sky is cut off by adjacent buildings or other obstructions, the shading effect of such obstructions may be determined by the method given in the previous report.[6]

This shading effect, and also the reflection of daylight from surrounding objects, will receive more detailed consideration in a later report.

DAYLIGHT ILLUMINATION ON SLOPING SURFACES.

The intensity of solar radiation on surfaces sloping in different directions should be of importance to agriculturalists and engineers.[7] Illumination intensities on such surfaces are of especial interest in connection with the lighting of industrial plants by means of the so-called saw-tooth-roof construction.

The computation of direct solar illumination on sloping surfaces presents no special difficulties. Let v, Figure 26, represent the angle between the sloping surface and a horizontal surface; w, the difference between the azimuth bearing of AF, the intersection of these two surfaces, and AB, representing the sun's azimuth; and x, the angle between the intersections of a plane in the

[6] Trans. Illum. Engr. Soc., vol. 16, p. 270; MO. WEATHER REV., Sept., 1921, 49: 486.
[7] MO. WEATHER REV., Nov., 1919, 47: 781.

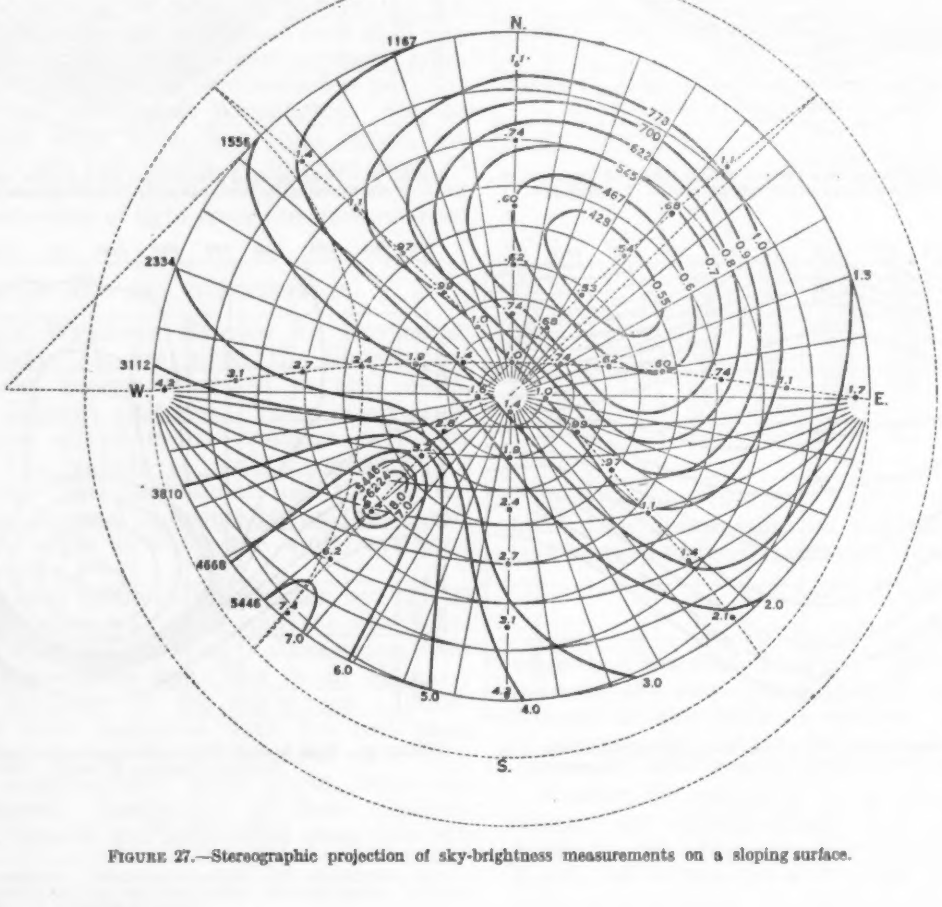


FIGURE 27.—Stereographic projection of sky-brightness measurements on a sloping surface.

sun's vertical with the sloping surface and with a horizontal surface. Then

$$\tan x = \sin w \tan v, \text{ and } a' = a + x \quad (3)\,[8]$$

where a is the altitude of the sun and a' is the angle between the incident solar rays and the sloping surface.

To obtain the intensity of solar illumination on a sloping surface we have only to substitute a' for a in equation (1).

We may also obtain a' by first determining the latitude and longitude of a point at which a horizontal surface is parallel to the sloping surface, by the method given in the MONTHLY WEATHER REVIEW, November, 1919, **47**:781.[9] Making allowance for the difference in time represented by the difference in longitude of the sloping surface and its parallel horizontal surface, we may obtain directly from an altitude table the altitude of the sun at the latitude of the horizontal surface, and therefore the angle a' which the incident solar rays make with the sloping surface at any hour of any day of the year.

The computation of the *skylight* illumination on sloping surfaces requires the replotting of the sky-brightness measurements for each surface considered.

Figure 27 shows the data for a clear sky with the sun at altitude 40°, projected on a surface for which $90° - w = 45°$ and $v = 10°$ (surface 80° out of the vertical and facing 45° in azimuth from the sun). In this case the zenith of the sky falls 10° from the zenith of the sloping surface. The line of the horizon from azimuth $+45°$ to $-135°$ with reference to the sun, and the lines on which the sky-brightness measurements are to be plotted, have been determined by means of the methods given under "Solution of Problems in Stereographic Projections" (pp.52–58), in General Theory of Polyconic Projections, by Oscar S. Adams, United States Coast and Geodetic Survey, Special Publication No. 57, Serial No. 110.

It is to be noted that the location of the line of the horizon consists in passing a circle through two given points, when the center of the circle falls on a given line. Or, it may also be determined by passing a circle through three given points, as is the location of the lines on which the sky-brightness measurements are to be plotted.

TABLE 8.—*Total illumination on surfaces sloping south.*

Date.	Hour angle of the sun from meridian.							
	0	1	2	3	4	5	6	7
	Foot-candles.							
	Surface sloping 10° from horizontal.							
Dec. 21	5,220	4,810	3,800	2,280	656	....	....	....
Jan. 21	6,000	5,590	4,560	2,910	1,140	....	....	....
Feb. 21	7,890	7,520	6,280	4,480	2,440	486	....	....
Mar. 21	9,250	8,800	7,660	5,880	3,660	1,560	82	....
Apr. 21	10,230	9,780	8,700	7,040	4,910	2,640	720	....
May 21	10,690	10,280	9,110	7,530	5,570	3,340	1,420	154
June 21	10,980	10,530	9,460	7,830	5,820	3,730	1,720	280
July 21	10,820	10,390	9,270	7,610	5,700	3,460	1,500	195
Aug. 21	10,050	9,660	8,580	6,920	4,790	2,620	710	....
Sept. 21	9,150	8,730	7,730	5,910	3,720	1,680	98	....
Oct. 21	7,550	7,220	6,090	4,280	2,250	440	....	....
Nov. 21	6,060	5,640	4,590	2,890	1,070	....	....	....
	Surface sloping 20° from horizontal.							
Dec. 21	6,300	5,820	4,690	2,890	900	....	....	....
Jan. 21	7,070	6,600	5,460	3,600	1,490	....	....	....
Feb. 21	8,870	8,500	7,140	5,120	2,910	600	....	....
Mar. 21	10,050	9,550	8,250	6,310	3,940	1,630	47	....
Apr. 21	10,770	10,310	9,050	7,250	4,950	2,540	630	....
May 21	11,060	10,490	9,230	7,510	5,400	3,100	1,180	141
June 21	11,260	10,640	9,460	7,750	5,610	3,360	1,380	232
July 21	11,180	10,590	9,320	7,580	5,570	3,220	1,190	156
Aug. 21	10,590	10,090	8,890	7,120	4,830	2,540	620	....
Sept. 21	9,930	9,450	8,310	6,360	3,980	1,680	61	....
Oct. 21	8,510	8,130	6,890	4,920	2,630	550	....	....
Nov. 21	7,130	6,660	5,500	3,580	1,380	....	....	....
	Surface sloping 30° from horizontal.							
Dec. 21	7,220	6,680	5,410	3,440	1,140	....	....	....
Jan. 21	7,790	7,360	6,190	4,150	1,820	....	....	....
Feb. 21	9,690	9,220	7,720	5,680	3,250	720	....	....
Mar. 21	10,640	9,990	8,590	6,550	4,110	1,700	50	....
Apr. 21	11,100	10,340	9,040	7,120	4,870	2,390	470	....
May 21	10,960	10,320	8,990	7,260	5,100	2,740	875	134
June 21	10,970	10,320	9,150	7,420	5,200	2,960	1,040	230
July 21	11,060	10,400	9,120	7,300	5,220	2,870	880	156
Aug. 21	10,910	10,210	8,900	7,020	4,650	2,650	500	....
Sept. 21	10,520	9,860	8,660	6,650	4,180	1,800	62	....
Oct. 21	9,250	8,790	7,420	5,380	2,940	650	....	....
Nov. 21	3,050	7,410	6,230	4,160	1,680	....	....	....

[8] In Daylight *vs.* Sunlight in Sawtooth-Roof Construction, Transactions American Society of Mechanical Engineers, 40:603-625, W. S. Brown derives this equation as follows:

$$\frac{AE}{ED} = \frac{\cos v}{\sin v} \therefore AE = ED \cot v.$$

Similarly, $AB = ED \cot x$; and $\sin w = \frac{AE}{AB} = \frac{\cot v}{\cot x}$, from which $\tan x = \sin w \tan v$.

[9] NOTE.—In lines 15 and 16 from the bottom of the second column of the page referred to, the words "longitude" and "latitude" should be interchanged. The difference in latitude between the sloping surface and its parallel horizontal surface is given by the equation

$$\tan \Delta\phi = \frac{\cos \alpha'}{\cot v},$$

and the difference in longitude by the equation

$$\sin \Delta\lambda = \sin \alpha' \sin v$$

where α is the azimuth in which the sloping surface faces, and v its angle of slope. When $\alpha' = 0°$ or $180°$, $\sin \Delta\lambda = 0$, and $\tan \Delta\phi = \tan v$. That is, the sloping surface and the parallel horizontal surface have the same longitude, and the difference in latitude equals the angle of slope, v.

TABLE 9.—*Total illumination on surfaces sloping toward southeast or southwest.*

Date.	Hour angle of sun from meridian.														
	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7
	A. m. for surface sloping SE.; p. m., SW.							P. m. for surface sloping SE.; a. m., SW.							
	Foot-candles.														
	Surface sloping 10° from horizontal.														
Dec. 21				816	2,530	3,920	4,680	4,830	4,120	3,080	1,620	302			
Jan. 21				1,420	3,260	4,680	5,490	5,580	4,920	3,740	2,130	623			
Feb. 21			756	2,980	4,950	6,500	7,420	7,370	6,780	5,330	3,500	1,610	180		
Mar. 21		171	2,120	4,340	6,390	7,960	8,800	8,890	8,180	6,760	4,840	2,790	907	48	
Apr. 21		1,240	3,330	5,630	7,600	8,990	9,730	9,970	8,140	7,930	6,010	3,890	1,850	305	
May 21	366	2,090	4,160	6,310	8,060	9,400	10,360	10,480	9,790	8,320	6,600	4,580	2,530	850	180
June 21	589	2,380	4,520	6,620	8,470	9,880	10,690	10,770	10,050	8,900	6,970	4,900	2,920	1,180	235
July 21	336	2,210	4,240	6,520	8,260	9,640	10,520	10,600	9,920	8,570	6,730	4,760	2,640	902	160
Aug. 21		1,130	3,330	5,540	7,520	8,960	9,710	9,800	9,150	7,850	6,000	3,870	1,890	330	
Sept. 21		190	2,170	4,380	6,430	8,010	8,730	8,820	8,130	6,890	4,920	2,850	939	63	
Oct. 21			676	2,710	4,740	6,310	7,110	7,180	6,520	5,040	3,380	1,520	184		
Nov. 21				1,320	3,230	4,700	5,540	5,640	4,970	3,760	2,110	594			
	Surface sloping 20° from horizontal.														
Dec. 21				1,260	3,360	4,880	5,560	5,550	4,650	3,310	1,580	232			
Jan. 21				2,040	4,190	5,740	6,420	6,310	5,340	3,920	2,060	467			
Feb. 21			1,130	3,990	6,020	7,560	8,340	8,120	7,150	5,380	3,250	1,270	157		
Mar. 21		253	2,790	5,290	7,370	8,820	9,470	9,160	8,260	6,580	4,400	2,190	485	38	
Apr. 21		1,610	3,960	6,590	8,400	9,720	10,290	10,170	9,030	7,500	5,330	3,100	1,060	270	
May 21	505	2,440	4,670	6,910	8,660	10,000	10,800	10,470	9,610	7,770	5,790	3,640	1,640	418	140
June 21	713	2,700	4,990	7,180	9,000	10,340	11,040	10,720	9,730	8,130	6,100	3,930	1,920	540	190
July 21	412	2,550	4,790	7,160	8,850	10,220	10,920	10,610	9,650	8,020	5,910	3,820	1,700	450	120
Aug. 21		1,430	3,900	6,270	8,270	9,650	10,270	9,980	9,070	7,450	5,350	3,110	1,110	250	
Sept. 21		276	2,770	5,220	7,370	8,910	9,430	9,260	8,250	6,700	4,530	2,300	500	52	
Oct. 21			1,010	3,510	5,720	7,310	7,970	7,840	6,870	4,900	3,160	1,200	163		
Nov. 21				1,880	4,160	5,730	6,480	6,360	5,350	3,950	2,050	451			
	Surface sloping 30° from horizontal.														
Dec. 21				1,670	4,180	5,740	6,280	6,080	4,960	3,380	1,530	175			
Jan. 21				2,660	5,090	6,580	7,140	6,800	5,580	3,970	1,940	325			
Feb. 21			1,490	4,850	6,940	8,410	8,950	8,480	7,290	5,220	2,900	859	174		
Mar. 21		334	3,230	5,910	8,090	9,500	9,930	9,460	8,140	6,240	3,880	1,600	450	46	
Apr. 21		1,990	4,600	7,150	9,040	10,340	10,650	10,010	8,700	6,850	4,550	2,240	540	250	
May 21	467	2,830	5,150	7,380	9,120	10,360	10,860	10,140	8,900	7,040	4,860	2,610	651	284	120
June 21	821	2,970	5,380	7,490	9,280	10,570	10,960	10,270	9,070	7,240	5,020	2,770	820	410	180
July 21	470	2,910	5,240	7,550	9,180	10,550	10,970	10,240	9,050	7,180	4,850	2,700	703	380	110
Aug. 21		1,790	4,350	6,790	8,770	10,160	10,530	9,830	8,630	6,780	4,540	2,180	580	270	
Sept. 21		350	3,340	6,060	8,110	9,650	9,650	9,370	8,040	6,280	3,950	1,660	455	58	
Oct. 21			1,320	4,280	6,540	8,120	8,530	8,140	6,890	4,740	2,840	859	143		
Nov. 21				2,450	5,060	6,640	7,210	6,880	5,640	4,000	1,950	319			

TABLE 10.—*Skylight illumination on surfaces sloping north.*

Date.	Hour angle of sun from meridian.							
	0	1	2	3	4	5	6	7
	Foot-candles.							
	Surface sloping 10° from vertical.							
Dec. 21	310	310	285	221	115			
Jan. 21	320	330	310	259	160			
Feb. 21	340	352	348	340	293	112		
Mar. 21	421	428	406	429	436	327	48	
Apr. 21	520	540	562	564	550	485	346	
May 21	554	600	660	685	641	650	590	228
June 21	580	640	758	770	740	790	719	365
July 21	580	635	733	730	712	700	630	288
Aug. 21	570	605	610	635	629	560	371	
Sept. 21	468	480	462	494	487	354	72	
Oct. 21	368	386	372	374	331	147		
Nov. 21	333	343	328	270	167			
	Surface sloping 20° from vertical.							
Dec. 21	355	350	320	236	112			
Jan. 21	362	365	355	276	172			
Feb. 21	390	400	410	395	294	120		
Mar. 21	489	498	471	516	486	416	46	
Apr. 21	619	635	638	640	642	589	412	
May 21	660	720	782	805	759	764	625	241
June 21	698	777	888	901	956	879	750	365
July 21	691	760	874	860	834	817	720	312
Aug. 21	671	710	715	730	730	660	418	
Sept. 21	542	560	538	558	555	411	60	
Oct. 21	430	446	460	420	338	122		
Nov. 21	378	394	366	278	182			
	Surface sloping 30° from vertical.							
Dec. 21	377	380	345	255	120			
Jan. 21	398	407	384	302	172			
Feb. 21	431	450	441	424	341	147		
Mar. 21	569	575	524	572	582	451	47	
Apr. 21	754	760	742	753	745	651	409	
May 21	801	873	913	882	898	871	643	200
June 21	830	920	1,035	1,028	1,035	1,004	770	337
July 21	837	917	998	990	980	962	655	217
Aug. 21	828	870	840	837	850	735	442	
Sept. 21	631	645	596	630	626	465	58	
Oct. 21	473	497	502	472	378	189		
Nov. 21	413	423	417	323	200			

TABLE 11.—*Skylight illumination on surfaces sloping northeast or northwest.*

Date.	Hour angle of sun from meridian.														
	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7
	A. m., sloping NE.; p. m., sloping NW.								P. m., sloping NE.; a. m., sloping NW.						
	Foot-candles.														
	Surface sloping 10° from vertical.														
Dec. 21				122	292	380	380	336	317	298	186	108			
Jan. 21				220	355	418	418	351	330	307	245	142			
Feb. 21			152	457	503	478	445	375	360	338	308	236	97		
Mar. 21		80	630	780	660	614	544	465	425	373	370	325	245	42	
Apr. 21		650	985	990	920	790	700	569	527	465	410	375	320	220	
May 21	450	1,150	1,300	1,240	1,100	1,010	815	624	575	540	485	425	430	330	150
June 21	600	1,350	1,500	1,325	1,383	1,070	900	661	600	590	533	478	475	400	180
July 21	450	1,220	1,500	1,300	1,130	1,200	870	660	600	585	510	440	450	380	120
Aug. 21		900	1,110	1,080	1,080	1,000	830	640	588	520	465	430	355	275	
Sept. 21		108	700	860	760	670	655	529	470	420	400	360	260	47	
Oct. 21			185	496	597	562	529	402	358	335	310	230	97		
Nov. 21				268	376	444	488	372	345	308	242	148			
	Surface sloping 20° from vertical.														
Dec. 21				170	337	405	440	391	370	308	225	105			
Jan. 21				230	402	480	525	418	385	340	257	145			
Feb. 21			202	502	580	580	565	440	420	380	345	250	98		
Mar. 21		78	640	755	785	705	660	547	495	425	370	360	245	38	
Apr. 21		720	980	1,050	1,010	935	810	676	625	550	485	440	355	225	
May 21	450	1,050	1,360	1,280	1,190	1,125	935	747	690	655	560	490	500	360	130
June 21	600	1,350	1,500	1,420	1,300	1,210	1,070	800	730	685	630	530	570	450	165
July 21	450	1,220	1,500	1,320	1,300	1,195	1,020	792	715	675	605	508	530	420	115
Aug. 21		900	1,080	1,140	1,220	1,080	920	760	685	610	535	480	390	240	
Sept. 21		105	680	935	1,010	803	750	624	560	492	450	375	262	44	
Oct. 21			185	500	684	680	638	488	460	425	365	260	91		
Nov. 21				247	424	518	556	440	394	340	275	125			
	Surface sloping 30° from vertical.														
Dec. 21				220	320	430	480	420	387	340	255	135			
Jan. 21				285	455	550	580	448	422	375	294	164			
Feb. 21			202	530	660	645	592	491	450	428	400	277	107		
Mar. 21		69	625	840	975	980	790	640	570	486	425	385	290	42	
Apr. 21		755	910	950	1,200	1,050	920	824	785	650	525	475	385	240	
May 21	450	1,050	1,320	1,350	1,380	1,300	1,100	888	830	800	665	530	535	390	120
June 21	600	1,350	1,500	1,450	1,360	1,350	1,180	941	855	840	738	595	600	445	220
July 21	450	1,220	1,500	1,400	1,400	1,320	1,160	949	870	835	695	575	535	420	140
Aug. 21		900	1,085	1,270	1,320	1,200	1,070	928	850	720	620	510	425	270	
Sept. 21		100	740	960	810	857	910	730	627	535	485	420	310	48	
Oct. 21			215	580	784	750	847	524	505	470	415	275	107		
Nov. 21				326	510	626	590	484	440	380	285	167			

TABLE 12.—*Ratio of total illumination, T, to sky illumination, S.*

CLOUDLESS SKY, LATITUDE 42° N.

Date.	Hour angle of sun from meridian. 0	1	2	3	4	5	6	7
	T, vertical surface facing south; S, vertical surface facing north.							
Dec. 21	29	27	22	22	16	......	......	......
Feb. 21	28	26	22	17	12	8	......	......
Apr. 21	13	12	10	7	4	1.4	0.3	......
June 21	9	7	5	3	1.1	0.3	0.2	0.1
Aug. 21	12	11	9	6	3	1.0	0.5	......
Oct. 21	25	23	20	15	11	5	......	......
	T, surface sloping south 10° from horizontal; S, sloping north 10° from vertical.							
Dec. 21	18	16	13	10	6	......	......	......
Feb. 21	23	21	18	13	8	4	......	......
Apr. 21	20	18	16	12	9	5	2	......
June 21	19	16	12	10	8	5	2	0.8
Aug. 21	18	16	14	11	8	5	2	......
Oct. 21	20	19	16	11	7	3	......	......
	T, surface sloping south 30° from horizontal; S, sloping north 30° from vertical.							
Dec. 21	19	18	16	14	10	......	......	......
Feb. 21	22	20	18	13	10	5	......	......
Apr. 21	15	14	12	10	6	4	1.2	......
June 21	13	11	9	7	5	3	1.4	0.7
Aug. 21	13	12	11	8	6	4	1.1	......
Oct. 21	20	18	15	11	8	3	......	......

HOUR ANGLE OF SUN FROM MERIDIAN.

Date.	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7
	T, surface facing SE., a. m., or SW., p. m. S, surface facing NW., a. m., or NE., p. m.								T, surface facing SW., a. m., or SE., p. m. S, surface facing NE., a. m., or NW., p. m.						
	Surfaces vertical.														
Dec. 21	....	....	....	28	29	28	24	20	12	7	2	0.7	....	....	....
Feb. 21	....	....	30	30	28	28	24	19	10	4	0.9	0.6	0.5	....	....
Apr. 21	....	14	17	22	21	17	13	9	4	0.9	0.6	0.4	0.3	0.3	....
June 21	6	8	11	16	14	11	9	6	1.6	0.7	0.5	0.3	0.3	0.3	0.3
Aug. 21	....	11	15	18	18	15	12	8	3	0.9	0.6	0.4	0.3	0.3	....
Oct. 21	....	....	24	25	25	24	20	16	9	4	0.9	0.6	0.5	....	....
	T, surface sloping 10° from horizontal; S, 10° from vertical.														
Dec. 21	....	....	....	8	14	13	15	14	11	8	6	2	....	....	....
Feb. 21	....	....	8	13	16	19	21	20	15	11	7	4	1.2	....	....
Apr. 21	....	6	10	15	18	19	18	17	13	10	6	4	2	0.5	....
June 21	3	6	10	14	16	17	17	16	11	8	5	4	2	0.9	0.4
Aug. 21	....	4	9	13	16	17	18	15	11	8	6	4	2	0.4	....
Oct. 21	....	....	7	12	15	19	20	18	12	9	6	3	1.0	....	....
	T, surface sloping 30° from horizontal; S, 30° from vertical.														
Dec. 21	....	....	....	12	16	17	16	14	10	8	5	0.8	....	....	....
Feb. 21	....	....	14	18	18	20	20	17	12	8	4	1.6	0.9	....	....
Apr. 21	....	8	12	15	17	16	14	12	9	7	4	2.4	0.6	0.3	....
June 21	4	7	9	13	13	13	13	11	8	5	4	1.9	0.7	0.3	0.3
Aug. 21	....	7	10	13	14	14	12	11	8	6	3	1.7	0.5	0.3	....
Oct. 21	....	....	12	16	16	17	17	16	8	6	4	1.4	0.7	....	....

On Figure 27 the brightness of the entire sky is shown, with the exception of a spherical lune which falls below the plane of projection on the side WNE., and for which the maximum width is 10° at N. The sky-brightness values that have been obtained by measurement on the half of the sky on one side of the sun's vertical have been plotted on both sides of this vertical.

In Tables 8 and 9 is given the total (solar + sky) illumination on surfaces sloping in southerly directions, as indicated. In Tables 10 and 11 is given the skylight illumination on surfaces sloping in northerly directions as indicated. In Table 12 is given the ratio of the total illumination to the sky illumination on surfaces facing opposite each other in azimuth.

Table 8 shows that in general on surfaces sloping south and with south solar declination the total illumination increases with v. With north solar declination the illumination reaches a maximum in the middle of the day when v equals about 20°, and decreases as v increases with the sun near the horizon.

Table 9 shows that in the morning on surfaces facing southeast, and in the afternoon on surfaces facing southwest, there is an increase in the total illumination with increase in v, except near midday in midsummer with v greater than about 20°. Also in the morning, on surfaces facing southwest, and in the afternoon, on surfaces facing southeast, the illumination generally decreases with increase in v, except near midday with south solar declination.

Tables 10 and 11 show an increase with v in skylight illumination on vertical surfaces sloping northward, as one would expect. It must be remembered, however, that with sawtooth construction a very considerable part of the skylight is cut off by shading. This is unimportant when considering the total illumination on surfaces sloping in a southerly direction, but becomes important in connection with the skylight illumination on surfaces facing towards the north, since it is the brightest part of the sky that is cut off.

Let it be assumed that the ridges of the saw teeth of the roof are horizontal, and of infinite length, and let θ = the maximum angular width of the spherical lune of the sky cut off. Then Table 13 gives the percentages of decrease in the skylight illumination,[10] due to shading by the adjacent saw tooth.

Table 12 shows that during most of the working hours of the day (except in midsummer) the total daylight illumination on surfaces sloping southward exceeds by more than tenfold the skylight illumination on surfaces sloping northward.

TABLE 13.—*Shading effect in saw-tooth-roof construction.*

90°−ψ.	Solar altitude. 20°	40°	60°	70°	θ
	PERCENTAGE OF SKYLIGHT CUT OFF.				
	Surface 10° out of vertical.				°
180	32	24	20	17	10
135	26	25	18	17	10
90	25	19	17	15	10
	Surface 20° out of vertical.				
180	43	37	31	25	
	Surface 30° out of vertical.				
180	30	33	24	21	20
135	38	28	23	21	20
90	34	26	24	18	20
180	53	44	33	31	30
135	50	41	33	28	30
90	46	37	33	30	30
	Surface 60° out of vertical.				
0	19	11	6	6	10
45	14	9	6	5	10
90	9	7	5	4	10
0	53	39	23	21	30
45	44	32	22	21	30
90	28	28	18	16	30
	Surface 80° out of vertical.				
0	11	6	3	3	10
45	9	5	3	3	10
90	4	3	2	2	10
0	35	29	18	15	30
45	32	21	13	12	30
90	16	12	10	9	30
0	64	54	36	30	50
45	55	42	28	27	50
90	30	23	20	19	50

[10] NOTE.—The percentages of Table 13 have been computed from Figure 27 and other similar figures. See also Trans. Illum. Engr. Soc., vol. 16, p. 270, and MONTHLY WEATHER REVIEW, Sept., 1921, 49: 486.

Computations from the sky-brightness data given in Transactions Illuminating Engineering Society, vol. **16**, p. 260, Figures 6 and 7, show that skylight illumination on vertical or sloping surfaces facing away from the sun is about twice as intense when the sky is covered with thin clouds or haze or partly covered with white clouds, which is its usual condition, as when clear. The total (solar + sky) illumination on surfaces facing the sun is usually diminished by the presence of haze or clouds of the above character. In consequence, when the angle *w* lies between about 45° and 135°, the ratios of Table 12 will be diminished, on the average, by at least one-half, and will vary in value from their maxima with clear-sky conditions, given in Table 12, to about 2.0 for a sky completely covered with dense clouds. This will be made clear from a comparison of the sky-brightness data of Figures 4 (opposite p. 259) and 13 (p. 263) with Figures 6, 7, and 8 (p. 260) and 11 (page 262), Transactions Illuminating Engineering Society, vol. **16**, October, 1921, and Figure 3 (p. 617) of this paper; and by reference to the illumination intensities of Table 4 (p. 618) of this paper.

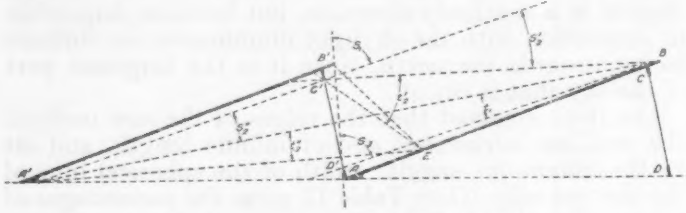


FIGURE 28.—Cross section of a saw-tooth roof.

These ratios are of use in computing the daylight that can be made available for illuminating working space in a building through saw-tooth-roof construction. In general, there are two sources from which the light may be obtained as follows:

(1) Light from the northern sky incident at the working space, or reflected thereto from the ceiling of the saw-tooth roof (sky angles S_1 to S_3, and S'_2 to S''_2, respectively, fig. 28).

(2) Solar and skylight reflected from the outside surface of the saw-tooth directly to the working space, or through a secondary reflection from the ceiling of the saw-tooth roof (roof angles t_1 to O, and t'_2 to t''_2, fig. 28).

It is to be understood that the angles here shown are cross-sections of spherical wedges.

Assuming the ratio of the intensity of the total light reaching the southerly-sloping roof surface of a saw-tooth window, AB (fig. 28) to the light received from the sky on the northerly-sloping window surface C'D' (fig. 28) to be 4, Brown[11] computed the relative values of (1) and (2) to be 14.6 and 6.1, respectively.

Let us consider a saw-tooth construction that gives a window surface facing north and sloping 20° from the vertical, and a roof surface sloping south 20° from the horizontal. Let the latitude be 42° north, the sky clear, the date March 21, and the hour 10 a. m., or 2 p. m., apparent time. The solar altitude will be 40° and its azimuth 41°. Disregarding shading, Tables 8 and 10 give 8,250 and 471 foot-candles for the illumination intensity on the roof surface and the window surface, respectively, the ratio of the former to the latter being 18.

The ridge of the adjacent saw tooth would cut off from the window a spherical wedge near the horizon for which the average value of θ would be about 10°. The window is facing 139° from the sun, and from Table 13 it is estimated that the shading by the roof diminishes the skylight illumination at the window surface 20 per cent. The roof between B and E will be in sunlight, and between E and A it will be illuminated by skylight only. We may therefore disregard the small quantity of light this latter can reflect to the under side of A'B'. The skylight from a spherical lune near the southern horizon for which θ averages about 30° will be cut off from BE by the adjacent saw tooth. From Table 13 we estimate that the illumination from skylight will be decreased by about 27 per cent. Therefore, the available sky illumination on the north-sloping window surface is $471 \times 0.80 = 377$, and on the south-sloping roof surface it is $1,100 \times 0.73 = 800$ foot-candles. The total illumination on the south-sloping roof surface is 7,950 foot-candles, and its ratio to the illumination on the window surface is $7,950/377 = 21$. Substituting this value for 4, we obtain for the relative values of (1) and (2) 14.6 and 32.0, respectively. Or, if we suppose the sky to be covered with thin clouds, or partly covered with white clouds, the values become 14.6 and 16.0.

Apparently, therefore, for clear-sky conditions, or even for the most usual sky conditions, when thin clouds or haze, or scattered white clouds are present, most of the daylight received through a saw-tooth-roof window will be from the reflection of skylight and sunlight from the roof of an adjacent saw tooth. In cloudy weather, however, nearly all the light will be received from the northern sky.

No attempt has been made to express the illumination intensity at the working space in absolute units. In order to do so, it is necessary to know the average of the solid sky angles S_1 and S_3, and of S'_2 and S''_2 (fig. 28); the brightness of the sky included in each of these angles, from which the sky illumination may be computed; the solar illumination intensity on the roof surface BE; the solid roof angle t_1, and the average of the solid roof angles t'_2 to t''_2; the coefficients of reflection of the surface of the ceiling A'B', and the roof, BE; the solid angle subtended by the ceiling at the working space, and the angle at which light is incident at the roof or the ceiling, and is received at the working space either directly or by reflection from the outside roof or the inside ceiling.

Of the above factors the brightness of the sky and the intensity of the solar illumination are given with reasonable accuracy in this paper for latitude 42° N. The remaining factors depend upon the design of the saw-tooth roof and its window openings, and must be determined for each individual case,

During the winter months, in a smoky city like Chicago, disregarding the probable decrease in the reflecting power of the ceiling of A'B', and the roof surface BE, the absolute values of (1) and (2) can not exceed 2/3 and 1/2, respectively, of their values in a comparatively smokeless region.

[11] Loc. cit., p. 620.

SOME METEOROLOGICAL ASPECTS OF THE ICE PATROL WORK IN THE NORTH ATLANTIC.

By Lieut. (Junior Grade) EDWARD H. SMITH.

[U. S. Coast Guard, Cambridge, Mass., Jan. 10, 1923

Next spring will complete 10 years of ice patrol service in the north Atlantic. During this period scientific investigation of the ice regions has been carried on with the object of increasing our general knowledge of these regions, and also of securing a more effective management of the patrol. Up to within a few years the behavior of ice in the Atlantic was a matter of conjecture. To-day charts are available showing the drift of bergs from the time of leaving the Labrador coast, the courses followed by these bergs being as carefully plotted as the track of a ship. Conditions are subject to much variation from year to year. Some years produce large quantities of ice; other years bring scarcely any. In some years the ice is held up in high latitudes; in others it drifts far south. Until now little time has been devoted to this aspect of the problem. The causes of variations in oceanic circulation, and similarly the behavior of ice from year to year, may be attributed to several factors. The meteorological aspects affecting the movements of ice will be considered later, but before taking up that matter a brief description of the International Ice Patrol Service may be interesting.

Ice which drifts south into the Atlantic every spring constitutes a great menace to steamships plying between Europe and the United States. In the days of slow steamers most of the vessels followed a great circle course between the two continental ports, which carried them through the ice zone a large portion of the year. Since the advent of the large and fast passenger steamers agreements have been entered into whereby definite routes have been established to the southward of the normal ice zone.

If the ice zone were fixed nothing further would be required to assure reasonable safety along the routes, but, as previously indicated, the limits of the ice fields and the bergs vary considerably in location as well as in season, and consequently a vessel might sail on a course that was clear at the time of her departure but collide with ice which had drifted into her path when she reached the vicinity of the Newfoundland Banks.

The establishment of the ice patrol followed directly the *Titanic* disaster, when the then largest ship afloat was sunk on the night of April 14, 1912, by striking an iceberg off the tail of the Great Bank of Newfoundland. In November, 1913, an international convention met at London, and among other subjects discussed the practicability of patrolling the ice regions. It was agreed to establish a permanent International Ice Patrol Service and the United States Government was invited to undertake the management of the service; the expense to be divided among the signatory powers in proportion to the amounts of their respective ship tonnages.

The work has two aspects: First, and of the utmost importance, is the determination of the variable limiting lines of menacing ice, and the dissemination of the information for the guidance of shipping; secondly, and coordinately with the first, is the making of such oceanographical and meteorological observations as will determine the causes of these variations, thereby increasing our knowledge to insure means of greater safety for life at sea.

A continuous patrol is maintained by two United States Coast Guard cutters capable of keeping at sea in all kinds of weather, each one alternately taking a two weeks' tour of duty and then being relieved by the other. When the ice scout approaches the ice region, it collects all information from near-by vessels and proceeds to search the area south of latitude 43° for signs of ice. It is the duty of the patrol to maintain contact with the southern, eastern, and western limits of ice as they vary in position throughout the season, and to broadcast this information to all approaching ships.

It can be seen from this duty as briefly described that a thorough knowledge of ice movements is absolutely necessary. In conjunction with its scouting duty, the ice patrol secures scientific observations relating to the area. Daily reports also are forwarded to the United States Weather Bureau. Previous scientific investigation of the vicinity of the Newfoundland Banks is negligible, except for the Murray and Hjort expedition on the *Michael Sars*, 1912, and the *Scotia* cruise, 1913, Mathews. Vessels' logs possess a large amount of data, but it is not easily accessible and is limited to the ocean surface. No true picture of oceanographical conditions can be obtained without consideration of the subsurface.

The three great ocean currents in the northwest Atlantic are well known, viz, the East Greenland, the Labrador, and the Gulf Stream. The East Greenland current is an overflow from the north polar basin of an accumulated mass of fresh water which has been discharged from northern Eurasian rivers and augmented during the summer by the water from melted ocean ice. The escape is southward past Jan Mayen along the east coast of Greenland, where the current bears great masses of heavy sea ice. The number of bergs is comparatively small, due to the scarcity of glaciers along the east coast. The East Greenland Current rounds Cape Farewell and continues northward along the west coast of Greenland to 65° N., where it begins to throw off branches westward to the Labrador Current. From 70° N. a northerly current is found along the coast as far as Cape York, where it turns sharply south in the east branch of a southerly current.

The polar drift, which has its source north of Smith's Sound, is made up of two branches, an eastern branch, consisting of the current just described, and a western branch which flows southward close to the American coast, being augmented by tributaries from Lancaster Sound, Jones Sound, etc. In Davis Strait the east and west branches join, forming the Labrador Current. Tracing the Labrador Current in its southern extension we find it floods the northern part of the Great Newfoundland Bank, a small branch escapes to the westward through the "Gully" under the Newfoundland headland. Greater quantities spread eastward in expansive surface layers, while the middle branch continues its flow along the east slope of the Great Bank. When the polar currents are swelled, arctic water spreads in over the Bank and across the southern end, otherwise the area over the Bank presents a characteristic identity that is at no time engulfed by either Labrador Current or Gulf Stream. The Labrador Current flows southwesterly around the

Tail of the Bank and impinges on the Gulf Stream which is flowing east past the Tail. The Gulf Stream, after it passes the Bank, spreads out in fan shape into several swirling bands and expansive ocean drifts. Upon meeting the Gulf Stream, the Labrador Current is frictionally arrested, then turned in toward the Stream, and lastly pulled along in an easterly flow parallel with the Stream, with a consequent interdigitation of polar and tropical water at the Tail of the Bank in the form of varied mixing eddies.

The statement that the Labrador Current is arrested in its flow and turned back parallel to the Gulf Stream is at variance with the views of many authorities who claim that the Labrador Current sweeps southwesterly across the Great Bank and continues as a cold current with a set down the east coast of the United States as far as Cape Hatteras. Another fact which has been brought out by the oceanographical work of the ice patrol is the lack of evidence to support the belief that the Labrador Current upon meeting the Gulf Stream dives beneath the latter, emerging to the southward. The evidence gathered by the patrol forbids such a view. On the contrary, the tendency of the polar water to spread out on the surface is quite pronounced. One ocean current may dive beneath another at some places in the world, but such is not the case here.

In the consideration of ice, it is necessary to make a distinction between field ice and berg ice. Field ice, formed by frozen Arctic sea water, is under the control of the winds and the surface currents. It is the first ice to drift south, putting in an appearance as early as January and February. At the latter date it often covers the entire area between the Newfoundland coast and the 43d parallel. In March and April it is noted most frequently on the southern part of the Great Bank. In low latitudes it is quickly melted and is by no means as dangerous as icebergs.

The great source of icebergs is the glaciers on the west coast of Greenland, from the region of Disko northward. When released by the breaking up of the field ice in summer the bergs are drifted around by ocean currents until they succeed in entering the Labrador Current. They first appear during March, drifting south along the east side of the Great Bank. During April, May, and June, bergs constitute a menace to steamships in this vicinity.

As stated above, the oceanic circulation and movements of ice are subject to continual variations which are attributed to several underlying factors, viz: (*a*) Meteorological conditions over the north Atlantic and Arctic regions, (*b*) the hydrodynamics of the Atlantic and Arctic basins, (*c*) variations in solar energy. In reviewing some of the literature upon the subject,[1] there is a modern tendency to stress the importance of the potential possessed by large bodies of water of similar character. The theory, briefly stated, is that the basic principle of oceanic circulation originates in the physical changes in water which manifests themselves in movements of a certain kind of a water mass from the region in which it abounds to the region where it is scarce. The volume and velocity of the induced current thus established will be governed by the supply and demand. Meteorological changes are factors in oceanic circulation which cause variations according as they increase or decrease dynamic forces. An example of this is a prevailing off-shore wind across the Gulf Stream that tends to push the surface layers of the Stream, from their normal course, but if this meteorological phenomenon be removed, normal positions are resumed.

In the northwest Atlantic probably the underlying cause of the Labrador Current is hydrodynamic conditions. Seasonal melting of the ice in northern regions causes an excess accumulation of cold fresh water to flood the surface between Greenland and North America. It seeks escape in a southward expansion on the warm saline water of the lower latitudes.

The variations in movements of the surface water are greatly influenced by the circulation of the atmosphere. They follow directly from the seasonal changes. The wind control is determined by the position, form, and intensity of the whole north Atlantic high-pressure area and by the cyclonic area to the northward. If the Icelandic minimum lie to the westward in the Greenland region, during the months of December, January, and February, the period when the field ice breaks loose, it will cause prevailing southwesterly winds which will retard the Labrador Current and tend to hold the ice in the higher latitudes. On the other hand, wind possessing a strong northerly component will tend to augment the Labrador Current and drift the ice south faster and in greater quantity than otherwise. The normal seasonal increase in size and intensity of the north Atlantic high during summer causes strong southwesterly winds which speed up the Gulf Stream. A great amount of warm water is accumulated in the eastern Atlantic basin which escapes to the northeast, even entering the polar basin. The reports recently received from Spitzbergen telling of unusually mild weather and open water where it is normally covered with ice may, if they are reliable, be attributed to a combination of favorable conditions, one of the individual factors being the atmospheric circulation over the north Atlantic.

Another matter of direct importance to the patrol is the probable relation existing between the distribution of the two kinds of ice in the lower latitudes during a given year and the meteorological conditions in northern regions during the previous year. Some work in this line has been done by Dr. Ludwig Mecking (1907)[2] and the conclusions reached are extremely interesting. In brief, these may be stated as follows: The amount of field ice appearing during the season off the Newfoundland Banks is compared with the mean barometric pressure gradient for December, January, and February, connecting two points which lie across the Labrador Current in the vicinity of the Labrador coast. The agreement is astonishingly good. The explanation is simple if we assume that the great source of the field ice is the Labrador coast, and that the gradient is a measure of the amount of off-shore wind which breaks the ice loose and permits it to drift southward.

The number of icebergs in any year in the north Atlantic is determined by the barometric gradient over the birthplace of the bergs in west Greenland during the previous summer. The assumption is that off-shore winds will drive a great number of bergs westward into the southerly current, thus preparing for a year unusually rich in bergs in lower latitudes. On-shore winds, on the other hand, tend to cause a poor ice year.

An attempt is being made, using the much more accurate data regarding icebergs in the vicinity of the Newfoundland Banks, to determine a possible relation be-

[1] Sandstrom, W.: "Canadian Fisheries Expedition, 1914-1915," pp. 221-291.
Pettersson, O.: "Connection between Hydrographical and Meteorological Phenomena," Quart. Jour. Roy. Met. Soc., July, 1912, pp. 123-191.
Dickson, H. N.: "The Circulation of the Surface Waters of the North Atlantic," Phil. Trans. Roy. Soc., London, 1906, vol. 196-A.
Bjerknes, V. E. K.: "Dynamic Meteorology and Hydrography," Carnegie Institute, Washington, 1910-11. Pub. No. 88.

[2] Mecking, L.: "Die Treibeiserscheinungen bei Neufundland," Annalen d. Hydro., Berlin, 1907, pp. 348-396.

tween the ice and the meteorological conditions based upon the last 10 years of the ice patrol work. Difficulty has been experienced in securing meteorological records from critical points on the Greenland and North American coasts.

It is unfortunate that there are not several year-round meteorological stations in northern regions. Besides the advantage which might be derived from their records, as just indicated, they might also serve as ice observation posts. If a station could be located somewhere along the side of the arctic drift where it sweeps in close to the shore, for instance at Cape Dyer, Baffin Land, it could serve the double purpose of a meteorological station and an ice observation post. The situation may be likened to that of a river. Flotsam observed upstream in the current will later appear at the river mouth. In this case the Labrador Current is the river whose mouth is in the vicinity of the Great Bank of Newfoundland; the flotsam is the icebergs. It takes approximately five months for a berg passing Cape Dyer to appear south of the 45th parallel. If the record of the number of bergs, with dates of passing Cape Dyer, were known to the ice patrol and the Hydrographic Office, long range forecasting of ice conditions in the North Atlantic would probably be possible. It would prepare us to meet and deal with a situation about which to-day we lack advance information.

POLAR ICE-DRIFT AND SUN SPOTS.

By GEORGE NICOLAS IFFT, American Consul.

[Bergen, Norway, Dec. 6, 1922.]

An interview with Dr. Adolf Hoel expressing doubt of the possibility of Amundsen's plan for drifting over the North Pole in the *Maud* with the supposed drift of the polar ice is attracting much attention throughout Norway and causing considerable discussion in the Norwegian press. Doctor Hoel, who is lecturer on geology at the Christiania University and who during the summer headed a government research expedition to Spitzbergen and the surrounding waters (see my report on "The Changing Arctic," transmitted under date of October 10, 1922), suggests that such drift over the pole would be possible, if at all possible, some years hence, upon the theory that the polar region is subject to fixed periodic changes and that such period affecting ice conditions is one of from 10 to 11 years closely connected with the known sun-spot periods.

Doctor Hoel states that the fact of the ice drift from the northern coasts of Asia and America across the pole to the strait between Spitzbergen and Greenland and then south along the east coast of Greenland has been shown by the drift of the *Jeanette* and other vessels. Amundsen's experience last year, however, seemed to indicate that the ice drift is subject to variations. At all events, the *Maud* did not succeed in getting into the drift because of unfavorable ice conditions and Doctor Hoel argues that it is reasonable to assume, either, that the exceptionally favorable ice conditions now prevailing at Spitzbergen are due to the fact that the polar current is weak and that the unfavorable ice conditions on the Asian and American north coasts are due to such cause or, that the ice in those regions actually moves in an opposite direction from that in which it has been believed to move.

Dr. H. T. Hesselberg, director of the Norwegian Meteorological Institute, discussing such suggestion, states that there can hardly be talk of a 10 or 11 year ice period in the polar seas without having submitted such theory to a thorough investigation and without a thorough study of the comparatively scanty material at hand. In regard to a relation between polar ice conditions and sun-spot periods, he said that the influence of sun spots is felt in so many conditions, among them atmospheric conditions, that it is not impossible that they also play their part in ice conditions about the pole. At the same time, he considers Doctor Hoel's statement of the utmost interest, as he is thoroughly familiar with conditions in that section of the world.

A REVIEW OF GEOPHYSICAL MEMOIRS NO. 19.[1]

By ALFRED J. HENRY.

[Weather Bureau, Washington, D. C., Dec. 28, 1922.]

The latest *Memoir* of the British Meteorological Office is a welcome contribution upon a subject of very great interest from both a theoretical and a practical viewpoint. It is peculiarly appropriate that this discussion of tropical cyclones should come from the English Meteorological Office, since it was Piddington, an Englishman, who first gave the name cyclone to the revolving storms of the Bay of Bengal more than half a century ago.

The raison d'être of the *Memoir* was an inquiry originating with the Colonial Secretary as to the visitation by tropical storms to the various dominions beyond the seas. Naturally the Meteorological Office was called upon to prosecute the inquiry. Obviously one of the first steps was to assemble in convenient form the enormous mass of widely scattered material from the original sources. The accomplishment of this object was entrusted to Mrs. E. V. Newnham, M. Sc., a member of the professional staff of the forecast division. How well she accomplished this difficult task may be seen by a perusal of the 102 closely packed quarto pages of text and charts.

The *Memoir* includes, in addition to the material collected by Mrs. Newnham, an introduction by Sir Napier Shaw, to which reference will be made later, and a short discussion by Dr. Harold Jeffreys on "Theories on the Origin of Tropical Cyclones."

The observational material is presented in four sections, each one dealing with those portions of the great oceans which are subject to visitation by tropical cyclones. These are:

(1) North Atlantic: A. West Indian Hurricanes.
B. Squalls and Tornadoes of West Africa.

(2) Indian Ocean: A. Cyclones of the Bay of Bengal and the Arabian Sea.
B. Cyclones of the South Indian Ocean.

(3) Pacific Ocean: A. Typhoons of the North Pacific.
B. Revolving Storms of the South Pacific.

The material is presented in great detail with many rather full extracts from the original papers. Thirty-three full page plates with numerous inserts illustrate the paper.

[1] Hurricanes and Tropical Revolving Storms, by Mrs. E. V. Newnham, M. Sc. With an introduction on The Birth and Death of Cyclones. By Sir Napier Shaw, F. R. S. pp. vi. 122 illus. H. M. S. O., 1922. Price 12s. 6d.

The indtrouction by Sir Napier Shaw was delivered as a lecture at a meteorological conference at Bergen, in July, 1920. The lecture begins with a short discussion of the maintenance and structure of cyclonic depressions from which the lecturer passes to a consideration of the subject of a revolving fluid in the atmosphere, a matter upon which he had made previous studies. It is specifically pointed out that if the fluid were carried along by a current the winds would represent not simply the rotation but combination of translation with rotation, a fact that is sometimes overlooked.

The subject of the lecture is further discussed under the following heads:

- Examples of cyclonic circulation.
- Localities of cyclonic depressions and tropical revolving storms in relation to the polar front.
- The extension of the polar front to the equatorial zone.
- The tropical anticyclones.
- The places of origin of tropical revolving storms.
- The thermal convection of hot moist air.
- The birth of a tropical cyclone.
- Precipitation.
- The death of cyclones.
- The height of cyclones.
- Descending and ascending air.

Each of the above topics is full of interest, especially to those who have been seeking to reconcile existing theories on the origin of cyclones. Since space will not permit a full abstract, the topic of greatest interest to REVIEW readers—"The birth of a tropical cyclone" has been selected for presentation in the fullness of the original.

In the immediately preceding section upon the thermal convection of hot, moist air, reference is made to certain sounding-balloon satistics for Java which give the normal lapse rate of temperature with height in the equatorial region. From Neuhoff's diagram [2] and equation the effect upon temperature of adiabatic changes of pressure in the case of air saturated with water vapor at, for example, 300° A. (about 80° F.) can be determined. Setting these data side by side it is seen at once that air saturated with water vapor at 300° A. would be in unstable equilibrium at Batavia, Java. If it began to rise it would not find itself at the same temperature with its surroundings, and therefore not permanently in equilibrium, until the level of 15 km. was reached, and only then if we suppose it to be loaded with its condensed water as drops. After they had fallen out, further height would be required to bring the density of the rising air to that of its environment.

Furthermore we may consider what would be the pressure at the surface if a column of air some 10 or 20 miles in diameter, for example, were replaced by the air which was saturated at the surface and thrust up into the heights. The pressure difference between an air column so defined and its environment can be computed, neglecting the humidity of the air in computing the density but allowing for it in the temperature. It appears that in these circumstances the difference in pressure between the exterior column and the environment would be as much as 81 mb. at the surface, gradually decreasing from that amount to 8 mb. at the level of 10 km. and to nothing at the level of 15 km. These facts are presented in the following table:

[2] Smithsonian Miscellaneous Collections, vol. 51, no. 4, 1910.

TABLE 1.—*Normal pressures and temperatures in equatorial air (Batavia) with the temperatures of air saturated with water vapor at 300° A. and reduced without any supply of heat to the pressure at the uppermost level, with the differences of pressure at different levels between the normal air and the column of saturated air.*

Height.	Normal air Batavia.		Saturated air changed adiabatically to same pressure at 15 k.		Pressure difference between the two columns.
	Pressure.	Temperature.	Temperature.	Pressure.	
k.	*mb.*	°*A.*	°*A.*	*mb.*	*mb.*
15	128	198	199	128	0
14	152	203	209	151	1
12	209	219	229	207	2
10	283	235	248	275	8
8	376	251	263	360	16
6	491	265	275	464	27
4	632	279	284	591	41
2	803	290	292	745	58
1	903	295	296	835	68
0	1,012	300	300	931	81

From the facts of the above table it is pointed out that this form of instability is very much dependent upon the temperature of saturation of the air, and it is therefore limited to regions where the air is not only very hot, but also very moist. Also, that the difference of temperature between the rising air and its environment reaches a maximum of 13° A. at 10 km.

It further appears that under suitable conditions the air of the surface is capable of rising to the heights which are actually characterized by convection in the equatorial regions, and that if a hollow column could be filled with it and protected by a rigid wall from its environment it would give rise to a difference of pressure at the surface of the same order as those found between the centers and margins of tropical cyclones and rather larger than is generally observed. The question arises as to how a hollow column can be provided automatically which will fill itself with air of suitable composition and temperature without bulging or collapsing. The author assumes, in explanation of this difficulty, that the interior column is protected dynamically by the spin of the surrounding air, and that the necessary velocity of rotation has been acquired by carrying away the air which originally filled the space now occupied by the interior column (and much more besides) in order that the convergence of the environment toward the region from which the air has been removed may develop the angular velocity of rotation necessary to provide a stable system with a core of very low pressure.

The foregoing serves as an introduction to the formal outline of the conditions which are concerned in the origin of a tropical cyclone. The ideas of Sir Napier Shaw on this very interesting and complex problem are given in his own words in the next section.

THE BIRTH OF A TROPICAL CYCLONE.

If we agree that the situation which is thus disclosed is strongly in favor of convection from the surface as the real agency in the formation of a tropical cyclone, we have still to consider the manner in which convection could produce the result. We have to recognize that *the first stage* is the removal of a very large volume of air *at all heights* so that the air at all levels may converge toward the axis and cause the superposition of a simple vortex upon the original rotational condition of the air.

It may here be remarked that, if there is no general tendency toward rotation which can be developed by convergence, the instability of the air will only be attended by a local shower and local disturbances

of wind, such perhaps as those of the doldrums, which are too near the Equator for the earth's rotation to be effective in originating a vortex.

The traditional view of the process of convection in meteorology may be described as the formation of a continuous local circulation, with a vertical portion caused by the continuous ascent of air in a particular locality in consequence of its relatively high temperature and a horizontal portion for the continuous replacement of the rising air by the pressing forward of colder air, which approaches from a considerable distance and itself becomes warm enough for ascent by the time it comes to the proper locality. The process is pictured in imitation of the continuous circulation which is set up in a vessel of water when one part of the bottom of the vessel is heated or in a system of heating by hot-water pipes; but in the atmosphere conditions are different; dynamical cooling introduces modifications which make the establishment of a continuous circulation, on the model of the laboratory or of the hot-water engineer, very difficult to trace or to imagine. The ascent of air becomes a question not merely of local warming, but of environment as well.

And apart from this fundamental difficulty the continuous pushing upward of a supply of air by distant pressure, acting like a continuous piston moving inward, would not provide for the necessary abstraction of air at all levels. On the contrary, it would seem to suggest the bulging of the sides of the column outward by the intrusive air. The traditional explanation does not take proper account of the fact that air only goes upward when it is pushed up.

Let us therefore consider more closely the process of convection. In the atmosphere convection may apparently proceed either by threads or bubbles. By the thread process, which may be operative on a sunny day when the surface is solarized, a thick layer covering an enormous area may be gradually brought into the condition of convective equilibrium for dry air. This is probably the case with the air over the Sahara or any other hot desert. The process is different from the formation of a huge bubble separated from the mass below through undercutting by the inflow of cooler air in the neighborhood. What conditions are necessary for the formation of bubbles on a very huge scale are not known, but it seems certain that when condensation begins bubble formation must be set up.

When a large bubble forms, it is pushed upward by the convergence of the air beneath it, and it pushes aside the air above it, the final result of the ascent of a single bubble being the convergence of the surrounding air at the level where the bubble was first formed. But as it passes upward eddies will be formed on its exterior, and some of the original column will be dragged up with it at the expense of some ascensional force. If we conceive the process of convection as the passage upward of a succession of innumerable large bubbles somewhat in the same manner as the escape of air from the neck of a bottle completely submerged, until many cubic miles of air have been lifted, the air originally over the area will have been gradually removed; the external air will have converged toward an axis and the beginnings of eevolving fluid will have been set up by the dynamical consequences of the original thermal process. Continued further, the same process will continue to remove the internal portion of the revolving column until the rotation has become sufficiently developed to resist further convergence toward the center. By that time, with the aid of the original vorticity of the earth's rotation, we shall have reached at all levels the condition of a simple vortex with a ring of maximum within which the pressure is kept low through the continual removal of air by what may be called the scouring action of the ascending bubbles. The axis then becomes practically unapproachable because the air that aims toward it is always deviated from its course. It takes part in the circulation and misses the convergence. So we get a dynamical system of great stability which admits air to the region of the axis only along the immediate surface, where the motion can not each the limit of protection, because it is retarded by friction.

So far we have a warm core with an environment the temperature of which, except at the very bottom, is governed by the dynamical cooling due to the convergence toward the axis. If the air of the environment contains sufficient moisture, cloud will form; and with the formation of cloud instability is probable, which will cause further condensation and possibly abundant rainfall outside the original column. All this can occur while the whole system is being developed in the easterly wind, and it moves with the wind toward the region where the surface water is still warmer, and consequently the surface air also becomes warmer; the dynamical process of scouring the central column is continued. But there will come a time when the supply of hot moist air at the surface is exhausted, and then the passage of the air through the column by ascent from the bottom must cease; the air can only rise until its temperature is the same as that of the cooled environment. When that stage has been reached, any hot air remaining in the column will be ejected at the top by the convergence from the sides, and we shall have obtained a dynamical system consisting of a vortex with a ring of maximum velocity of finite diameter and its interior protected from further invasion, except at the bottom, by the velocity of rotation, so that it can only be affected by the creeping of air or other material into the interior along the bottom. The temperature distribution will be that produced by convergence of the environment toward the axis; the whole effect of the convection, originally due to the heated and saturated surface air, will have been to cause the removal of the air from along the axis, which Lord Rayleigh's exposition requires for the formation of a vortex of revolving fluid. Thus the high temperature of the interior is merely a temporary incident in the formation of a cyclone vortex; by the time the vortex is developed as a dynamical system the core is cold; there is no longer any convection in it; it becomes a comparatively small area, protected from the ordinary vicissitudes of weather by the enormous momentum of a vortex with a high rate of spin, represented by the very violent winds of a certain ring, but extending in less violent form over a vast area.

It may be noticed that the ultimate violence of the winds of the maximum ring depends on the limitation of the area of convection. Since the velocity in the vortex varies inversely as the distance from the axis, if convection can be effective in removing the necessary amount of air without using an area greater than a half kilometer in diameter, the wind at a distance of 1 kilometer from the axis will be only one-quarter of the maximum. The shape of the curve $v_2r=$ constant, in Figure 1 [not reproduced] will approach much more nearly to the two axes.

The discussion on "Theories of the Origin of Tropical Cyclones," by Dr. Harold Jeffreys in the following paragraphs is most helpful to a clear understanding of this complex problem:

THEORIES ON THE ORIGIN OF TROPICAL CYCLONES.

The cause and dynamics of tropical storms are still very imperfectly understood, but a few important features are fairly clear. It is a well-known phenomenon that when a body is in slow rotation at the commencement, and is drawn toward some fixed center the velocity of each particle of the fluid increases as it approaches the center. If the motion is perfectly symmetrical, the velocity of a particular particle about the center is inversely proportional to the radial distance. The most familiar instance of this is the swirling motion that is developed in a bath when the plug is withdrawn from the bottom; the effect of the displacement of the water, from an average distance of a few feet from the center, to about an inch from it, is sufficient to increase the inappreciable rotation that was present at the commencement into a vigorous vortex. There can be little doubt that the rotation of a cyclone is produced by such a displacement toward the center. The initial rotation in this case arises chiefly from the rotation of the earth, since the actual motion of the air at any place is the resultant of the motion of the ground below it and the observable wind, the former of which is by far the greater. If now the center be north of the Equator, we see that the true eastward velocity north of it due to rotation of the earth is less than the velocity on the south side, the difference being such as would be produced by a counterclockwise rotation about the vertical. This being magnified by an approach of the air to the center, a counterclockwise whirl is developed. The opposite is true in the southern hemisphere. Thus, if this analogy is correct, all cyclones in the Northern Hemisphere should rotate counterclockwise, while all those in the Southern Hemisphere should rotate clockwise. This invariable difference in the directions of rotation of storms north and south of the Equator is one of the best known facts about these storms, and affords an immediate and convincing verification of this part of the theory.

If, however, the surrounding air near the ground approached the center without any outward displacement taking place above, there would be an accumulation of air above the central region, and consequently a real increase of atmospheric pressure there; whereas we know that the pressure in the middle of a cyclone is lower than elsewhere. Hence, while the air on the ground is moving inward, that above it must move outward; and the reduction of pressure inside shows that the amount of air that moves outward above must be greater than the amount that moves inward below. Such an outward motion of the upper clouds is suggested, though scarcely proved, by the distribution of the "cirrus," which is usually described as radiating from the center.

As the outward and inward motions appear, so far as can be detected from the phenomena observed while the cyclone is developing, to occur simultaneously, it is not easy to say which of them is cause and which is effect. It is natural, however, to suggest that the outward motion, being the greater, is the cause of the other. Now if such an outward displacement took place in the upper air, it would leave behind it a region of reduced pressure, and the lower air would flow in toward the center on account of this. Further, it is unlikely, on account of inertia and friction, that this would take place so rapidly as to neutralize the diminution of pressure completely, so that a low pressure would remain. Thus an outward displacement of the upper air affords an adequate explanation of the distribution of wind and pressure at the surface.

Two types of theory have been advanced to account for tropical cyclones; in their essential features they are both consistent with

what has already been said, but they differ in the causes assigned to the outward displacement, which is a necessary feature of both. The first of these is the convectional theory. This requires a local heated region, over which a column of very moist and warm air develops. The initial effect of both the heating and the evaporation is to cause an increase in the volume of the air affected, and hence the upper air is lifted up by the expansion below it. It then flows out so as to readjust its level, giving the outward displacement we need for our theory. The formation of clouds and rain in the lower air is a consequence of the fact that as the air moves inward it comes to a region of lower pressure, where it expands and cools to some extent, and consequently can not retain all the water vapor it held previously.

One difficulty of this theory is that these storms always form over the ocean, and always in summer. The land in summer becomes much hotter than the sea, and therefore we might expect on this theory that more cyclones would take place on land than at sea, whereas actually they all originate at sea. This objection would be met if it were shown that moisture is much more important in producing these distrubances than a rise in the temperature of the ground, equal to the difference between the summer temperatures of land and sea, would be. For this to be true requires a very high vapor pressure in the saturated air, which can only be obtained near the equator. This may, therefore, be the reason why revolving storms of this type are confined to the tropics.

Another difficulty is that the conditions over vast areas of the ocean must be very uniform, and that there is little reason why one region 200 kilometers across should be singled out as the place of origin of a storm rather than any other. It may be, however, that the whole of an extensive region is on the verge of developing into cyclones, and that only a trifling difference is needed to localize the disturbance when it develops. A way in which an outward displacement may arise from such a difference and lead to a persistent storm is described by Sir Napier Shaw in his introduction.

It may be remarked that it is not necessary to the continuance of a storm that the causes that brought it into being should retain all their efficacy. In particular, it is not necessary that a strong vertical current should persist. When the revolving column is started, mere inertia will keep it going for a considerable time in spite of friction. This is probably the chief reason why such storms are able to move so far toward the poles when they have once been formed.

A revolving storm would naturally be expected to have a motion of translation on this theory. The conditions of its formation require it to start in the Tropics, but not at the equator, since a storm formed at the Equator could acquire no rotation. Thus all such storms start in the regions of the trade winds, and the air forming their cores has initially the general motion of the places where they form. It retains this, only changing it in consequence of the widespread pressure difference in the regions through which it passes. Thus these storms have usually velocities of translation not very different from those of the general winds of their surroundings.

The chief alternative theory is the mechanical theory first suggested by Dove, supported by Thom, Meldrum, and Fassig. The formation of circular whirls at the boundary between opposing currents of water in a millpond is wellknown, and this theory suggests that tropical cyclones develop in much the same manner at the boundary between two winds of extent comparable with 1,000 kilometers or more. The velocities in these millpond eddies, however, never exceed those in the main current, while those in tropical cyclones always do so. In the absence of quantitative dynamical investigation, it would therefore be very dangerous to adopt the theory in this simple form as an explanation of tropical storms, though it might do for those of the Temperate Zone. Nevertheless it is true that such conflicting winds do exist on opposite sides of all the zones of formation of tropical cyclones, and that the only ocean in which there is no region flanked by opposite currents is the south Atlantic, where these storms do not occur. What probably happens is that the meeting of these winds leads to the formation of eddies and ascending currents, and that these form an important stimulus in deciding the locality of formation of cyclones according to the convectional theory. The most probable explanation is to be found therefore in a combination of the two theories.

RELATION OF WEATHER CONDITIONS TO WIRELESS AUDIBILITY.

By M. P. BRUNIG.

[Nebraska Wesleyan University, University Place, Nebr., July 20, 1922.]

SYNOPSIS.

This article gives a brief résumé of work previously accomplished showing the relation between meteorological conditions and wireless audibility. Diagrams and explanation of a similar experiment carried on at Nebraska Wesleyan University are then given, and the curves obtained by means of the experiment show no relation between barometric pressure and audibility, no influence of conditions at sending station on audibility conditions at a distant receiving station, but do show that high static frequency, high static audibility, and a near-by thunderstorm area tend to reduce the audibility at the receiving station.

In the early investigations in the receiving of wireless messages it was noted that atmospheric disturbances greatly interfered with the receiving of signals at times and that the signals came in with varying intensities at other times with no apparent cause. This varying of signals, called "fading" or "swinging," was the subject of an investigation reported by J. H. Dellinger and L. E. Whittemore,[1] who found that the effect was more noticeable on land than on water, also more pronounced at night than in the daytime, although signals were stronger at night than in the daytime. In February, 1921, L. W. Austin[2] reported a series of observations on "The relation between atmospheric disturbances and wave length in radio reception," which gave the most complete information available at that time regarding atmospheric effects on signal receiving by wireless. Other important observations along this line were made by J. H. Dellinger and L. E. Whittemore,[1] Francis W. Reichelderfer,[3] E. W. Marchant,[4] and H. Mosler.[5] The static interference is worse at night than in daytime according to these and other investigators.

[1] *Jour. Wash. Acad. of Sci.*, vol. 11, No. 11, June, 1921.
[2] *Proc. Inst. Radio Eng.*, Feb., 1921.
[3] MO. WEATHER REV., Mar., 1921.
[4] *Electrician*, Feb., 1915.
[5] *Electrician*, Jan., 1914.

The present experiment, which was planned for the purpose of gathering more information concerning the relations between radio signal audibility and weather conditions, was begun in 1919, but it was not until the autumn of 1921 that final arrangements were made to take observations under controlled conditions. The circuit shown in Figure 1 was used for these observations.

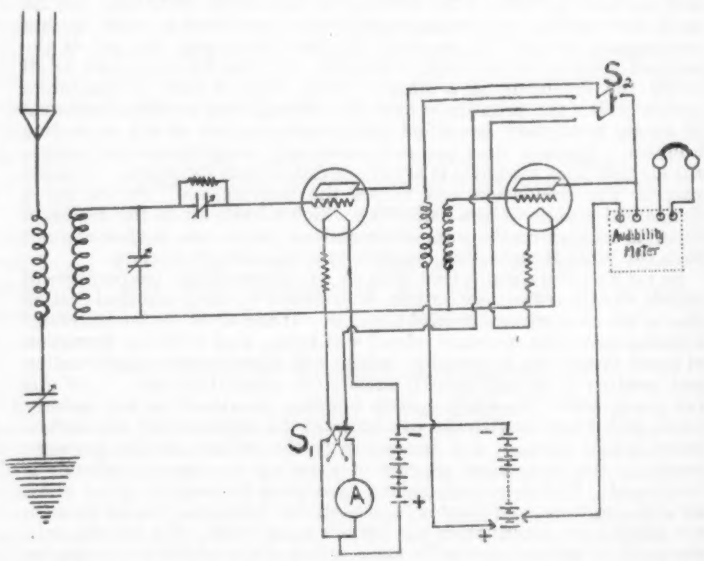


FIGURE 1.—Circuit used at Nebraska Wesleyan University for audibility measurements, 1921–22.

To insure constancy in the receiving conditions the following precautionary measures were taken: The tuning coil used was of the Navy type with contacts numbered and a scale and pointer adjusted so that exactly the same

setting would be used each time; each condenser used had a scale which enabled repetition of settings with accuracy; switch S_1 with accurate ammeter (A) was put in so that the filament current in either the detector or amplifier tube could be accurately measured by the same instrument without change of connections; S_2 was placed so that the circuit could be used as a simple detector or with the first stage of amplification, it being desired not to use the amplifier unless necessary, thereby reducing the possibility of increased error through the more complicated amplyfying circuit. The block of cells forming the "B" battery, dropping only from 31½ volts to 31 volts during the whole course of the experiment, maintained a constant plate potential. A pair of Brandes Navy phones and the constant impedance type of audibility meter shown diagrammatically in Figure 2 were used. This receiving set was used for the research work only and kept in careful adjustment, a simple switching arrangement making it possible to change to the regular receiving instruments at will.

For the first part of the experiment vacuum tubes of the VT-1 type were used and readings taken on signals from KDEF, the Army radio station at Omaha, Nebr., a distance of about 50 miles. The first-stage amplifier was used through this set of readings. Unfortunately, late in August the tubes began to show evidence of not remaining constant and began "howling." All readings

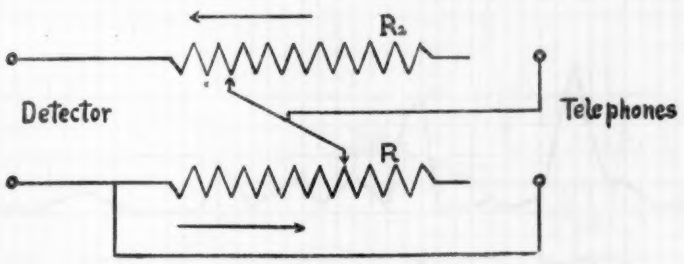


FIGURE 2.—Constant impedance audibility meter.

of this set later than August 11 were discarded. The results obtained are shown by the curves in Figure 3.

October 8, 1921, a new set of readings was begun on signals from NAA, the Arlington Station, using detector-tube circuit only. This tube was of the A. P. type and continued constant throughout the observations taken for Figures 4, 5, and 6. Readings on KDEF were taken at 9 a. m., those on NAA at 9 p. m., and those on 9YT, Wayne Normal (distance about 100 miles), were taken at 4:15 p. m., Central Time.

From these curves it appears that the three most important factors affecting audibility are (1) static frequency, (2) nearness of thunderstorm area to receiving station, (3) static audibility. Apparently the barometric conditions have very little or no effect on audibility. The barometer readings and miles to nearest thunder area were taken from the United States weather map for the corresponding 24 hours. The static frequency was based on the percentage of time that static could be heard; that is, if continuous, the frequency was recorded as 10; if only very occasional silences, 9 was recorded; for half time 5 was recorded, etc. This method is open to some criticism, but since the static is such a varying quantity as regards volume, pitch, intensity, and continuity of separate sounds, no satisfactory method of accurate measure was available. For static audibility, the audibility of the "crashes" was used where they were noticeably stronger than the prevailing "grinders" instead of counting three pulses per second as audibility, according to Austin's method.

Conspicuous dates for low audibility apparently affected by the three factors mentioned are July 18, August 10, November 16, 17, 18, 19, February 27, 28, March 6, 13, 14, April 7, 10, 13, and May 3 and 10.

Conspicuous dates for high audibility apparently affected by the three factors are August 8, October 8, 19, November 21, December 13, 20, February 24, March 2, 4, 11, April 5, May 16.

The following dates, however, seem to contradict the general indications of the three factors and can only be explained on the basis of the fading phenomena, a complication of conditions, or errors in observations: July 20,

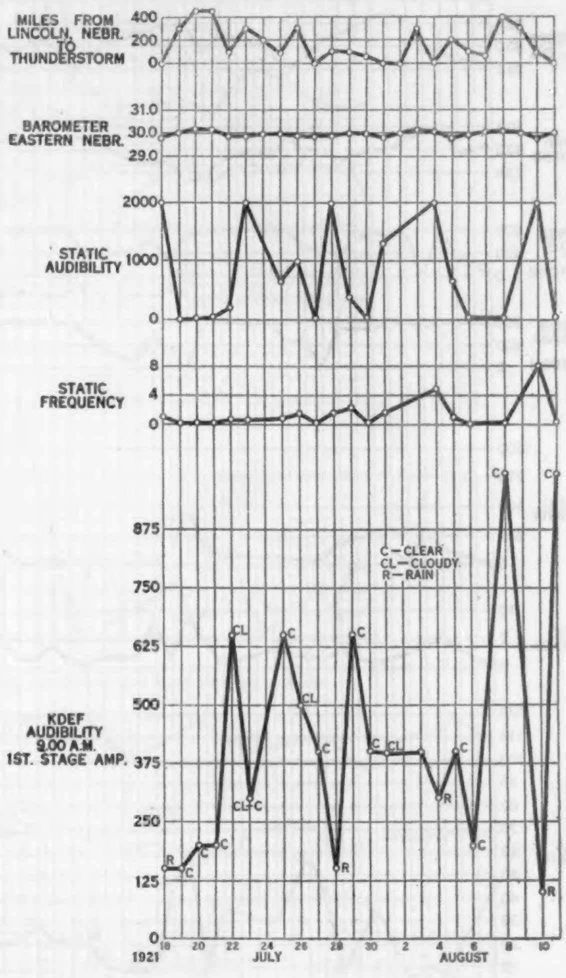


FIGURE 3.—Results of observations upon meteorological conditions and their relation to radio.

21, 22, and 29, August 11, October 13, December 9 and 14, April 1.

The following causes may be given as apparent causes for variations noticed in readings: (*a*) Reports of thunderstorm distance as given by the Weather Bureau may be for more or less local disturbances which had not yet taken place or were dissipated by the time the observations were taken; (*b*) while frequency may be reported as 10, the average audibility may be very low and a high audibility reported on account of intermittent crashes of short duration which do not seem to seriously affect audibility. Such a condition existed on December 3 when frequency is recorded as 9, audibility as 300, but the thunderstorm area was 800 or more miles away and

NAA came in with an audibility of 120, which is far above the average for that period. The possibility of such complications, known or unknown, is so great as to be a serious obstacle in forming any laws or reaching definite conclusions regarding the relationship existing between audibility and meteorological conditions.

These observations agree with those of previous observers as regards the audibility and frequency of static being stronger in summer than in winter. It does not seem probable that these readings or any so far recorded give any hopes that weather conditions may be forecast by direct radio observations. There is nothing in these curves to show any relation between barometer readings and audibility. Granting that by the use of direction finders and audibility of static one could tell direction and distance of thunderstorm area, necessary factors for forecasting would still be missing.

However, weather forecast maps could be used to advantage by a sending station to gain some idea of receiving conditions at the receiving station. Where the stations are several hundred miles apart, as is the case with Nebraska Wesleyan University and Arlington, the curves obtained would go to show that local weather conditions at the sending station have no effect on the audibility at the receiving station. A phone message sent out from this station during a local thunderstorm was heard distinctly and clearly at a distance where there was no storm.

It is well known that due to variations of the individual ear and temperament from day to day, the audibility method is not accurate to within 20 per cent on single observations. To offset this in the recorded observations, at least three sets of readings were taken in almost every instance and the average used. At times it was necessary to wait nearly half an hour for local noises that could not be eliminated to cease, in order to take readings under normal conditions. But an allowance could be made for as much as 50 per cent on the recorded readings and the final conclusions affected little if any.

To check the accuracy of the observations, a Hartley oscillation circuit was set up as in Figure 7, a double-throw switch S set so that, using the same telephone receiver, the audibility of Arlington might be immediately compared with the audibility of the secondary of the constant audibility circuit. A thermo-galvanometer G was placed in the secondary of the circuit and in series with four 1-ohm resistances, *a*, *b*, *c*, *d*, placed in parallel. Resistance *a* was of the slide wire form and the sliding contact enabled the observer to get the drop in potential across a small portion of the 1-ohm resistance.

Letting I equal the current through ab of the secondary circuit and ax equal the portion of ab across which the telephone is shunted, then, if the audibility factor of the human ear remained constant, the quantity $I \cdot \frac{ax}{ab}$ should also be constant.

FIGURE 4.—Results of observations upon meteorological conditions and their relation to radio.

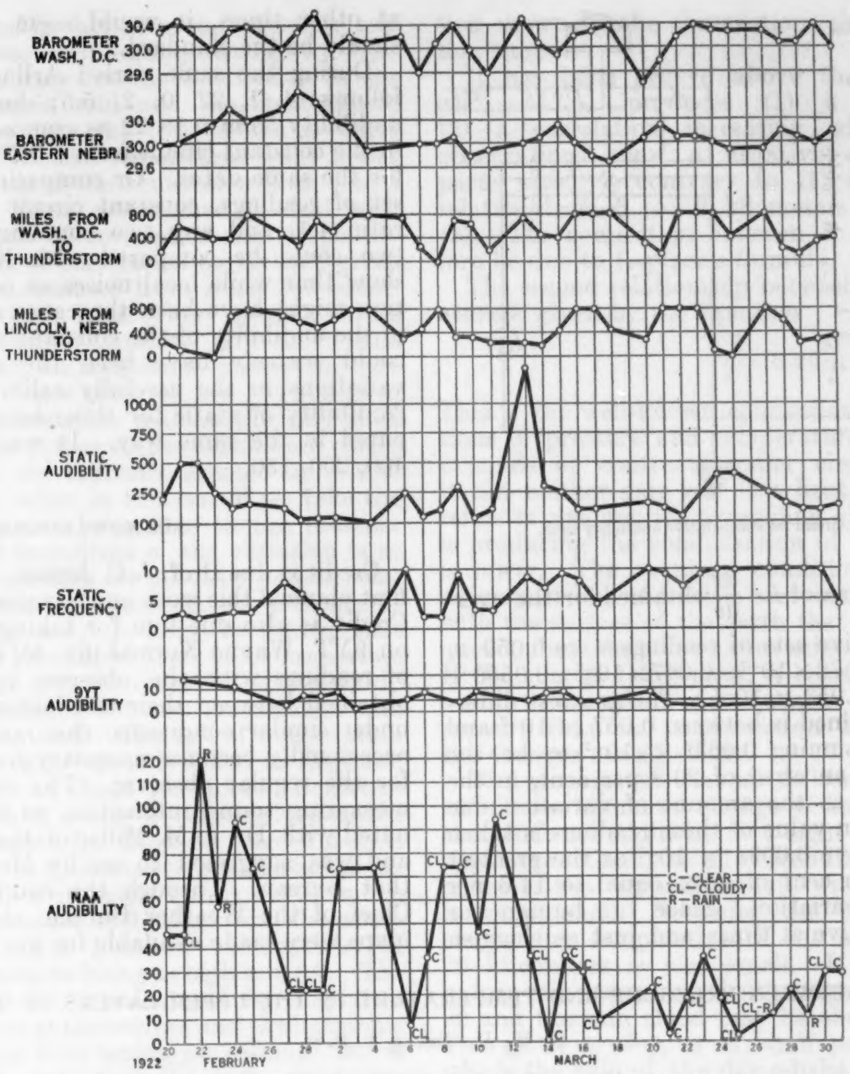


FIGURE 5.—Results of observations upon meteorological conditions and their relation to radio.

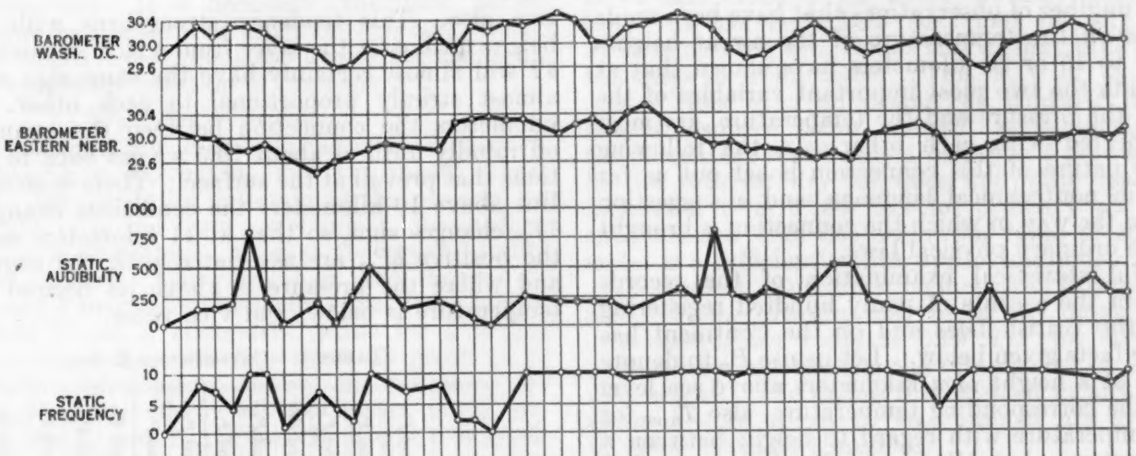


FIGURE 6.—Results of observations upon meteorological conditions and their relation to radio.

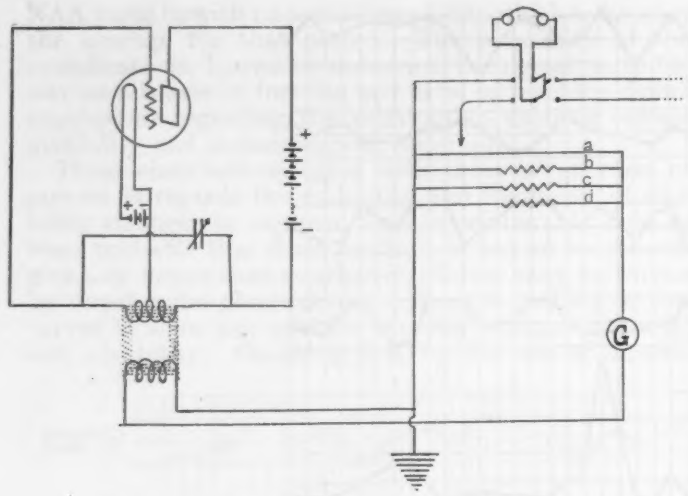


FIGURE 7.—Oscillation circuit for comparative audibility tests.

To illustrate, the values of $I \cdot \frac{ax}{ab}$ obtained for the averages of seven consecutive sets of readings were 0.059×10^{-7}; 0.065×10^{-7}; 0.0572×10^{-7}; 0.067×10^{-7}; 0.0556×10^{-7}; 0.055×10^{-7}; 0.053×10^{-7}. The greatest difference in the values obtained is between 0.067×10^{-7} and 0.053×10^{-7}, and assuming 0.067×10^{-7} to be the correct value we have an error of 20.8 per cent, in the reading 0.053×10^{-7}, as the amount of variation due to the ear. If the mean value of these readings is taken (0.0588×10^{-7}), we have 0.0098×10^{-7} as the greatest error, which gives a per cent of error equal to 14.6 per cent as the greatest variation. Since the human ear is extraordinarily sensitive at times and just as sluggish at other times, it would seem that the mean record should be the standard.

During the same period Arlington audibility was as follows: 4, 1, 22, 0, 2, 5.5; showing a fluctuation of audibility from 0 to 22 as compared with a fluctuation in the constant circuit from 0.0572×10 to 0.067×10^{-7} for the same dates. Or comparing the first two in each set of readings, constant circuit ratio 59:65, Arlington ratio 4:1, and any two consecutive readings on these two could be compared with like showings. Results show that while local noises or personal physical condition might have been the cause of the small variations in the audibility of the constant circuit, the same causes could scarcely have been the cause of the extreme variations in the carefully calibrated receiving circuit. Audibility of static for these seven days could be compared in the same way. It was 200, 500, 1,000, 200, 400, 200, 150.

ACKNOWLEDGMENTS.

Credit is due Prof. J. C. Jensen, who, in 1916 or earlier, first planned this work and has since directed its progress. Credit is also due him for taking the series of readings on 9YT, Wayne Normal (fig. 5), and for taking a series of readings with the observer by which a ratio was obtained between their audibilities on the same station under similar conditions, this ratio being used when it occasionally becomes necessary for him to take readings for the regular observer. The comparison method for measuring sound intensities, as shown in Fig. 7, originated with Dr. J. M. Miller of the Bureau of Standards and was suggested to us by Mr. L. E. Whittemore of that Bureau. Through the courtesy of C. F. Marvin, Chief of the Weather Bureau, the large daily weather maps were made available for our use.

THE CONNECTION BETWEEN PRESSURE AND TEMPERATURE IN THE UPPER LAYERS OF THE ATMOSPHERE.

By W. H. DINES, F. R. S.

[Benson, Wallingford, England, Aug. 30, 1922.]

The large number of observations that have been made over Europe on the temperature of the air at heights reaching up to 15 or 20 kilometers have shown that at certain heights the two most important variables of the atmosphere, the pressure and the temperature, are most closely connected with each other. In the following remarks the nature of this connection is set out as far as possible in nontechnical language, and a suggestion is made as to the way in which the connection is brought about by the ordinary physical laws.

The careful statistical examination of the records obtained from the ascents of many hundred registering balloons in the British Isles and on the Continent has disclosed the facts given below. Let us use P_n to denote the pressure at a height of n kilometers above sea level and T_n for the corresponding temperature, also $T_{n,m}$ for the mean temperature with regard to height between n and m kilometers. Let δP denote the departure of P from its mean for the geographical position and the height and δT the corresponding quantity for the temperature. Then at the surface there is found to be no connection between δP_0 and δT_0, if the barometer is high so that δP_0 is positive there is no tendency for the temperature to be either above or below the normal value. At 1 kilometer, however, a bias is beginning to appear, if δP_1 is positive there is a distinct tendency for δT_1 to be positive also and if δP_1 is negative δT_1 is probably negative also. This tendency strengthens with increasing height until over the layer from 4 to 8 kilometers δP and δT will almost certainly have the same sign and will be almost strictly proportional to each other. Above 8 kilometers the connection between the quantities falls off rapidly until at about 10.5 we get back to the conditions that prevail at the surface. There is no connection. But above 10 kilometers the conditions change and the δT_{10} changes sign, so that at 11 kilometers and upward the positive δP_{10} are associated with the negative δT_{10}, and where the pressure is above its normal value the temperature is below, and vice versa.

TABLE 1.—*Correlation coefficients.*

	T_0 and P_0.	T_1 and P_1.	T_2 and P_2.	T_3 and P_3.	T_4 and P_4.	T_5 and P_5.	T_6 and P_6.	T_7 and P_7.	T_8 and P_8.	T_9 and P_9.	T_{10} and P_{10}.	T_{11} and P_{11}.	T_{12} and P_{12}.	T_{13} and P_{13}.
January to March	−0.02	0.54	0.82	0.79	0.86	0.85	0.84	0.87	0.91	0.81	0.35	−0.32	−0.38	−0.37
April to May	.14	.28	.49	.79	.89	.89	.92	.87	.81	.45	.20	−.12	−.24	−.01
June to September	−.02	.31	.56	.72	.75	.81	.83	.87	.87	.88	.43	−.08	−.41	−.19
October to December	.33	.56	.76	.77	.83	.87	.85	.85	.86	.78	.29	−.24	−.34	−.50
Means	.11	.42	.66	.77	.84	.85	.86	.87	.86	.71	.32	−.19	−.36	−.28

These figures are taken from *Geophysical Memoirs* No. 13 (M. O. 220c), published by the Meteorological Office, where many other correlation coefficients are given in detail.

This general relationship between the pressure and the temperature was discovered many years ago by Teisserence d'Bort. It is simply the statement that in the cyclone the troposphere is cold and the stratosphere warm and in the anticyclone the troposphere is warm and the stratosphere cold; the remarkable point about it is the extreme closeness of the connection from 4 to 8 kilometers height. To those accustomed to deal with statistical data by means of correlation this is plainly brought out by the table of correlation coefficients given above. The values are obtained from some 200 observations made in the British Isles. Very similar values hold for the Continent and for Canada. The coefficients are uncorrected for the observational errors and are on that account about 5 per cent too low. Thus from 5 to 8 kilometers the correlation reaches the very high value of 0.90. Since the square of the correlation coefficient is the measure of the influence exerted by one of the quantities upon the other, in this case if we take the variation of temperature as being due to the pressure changes it appears that four-fifths of the variation is so produced leaving only one-fifth for all other causes combined, such as the direction of the wind, the presence or absence of cirrus cloud, etc. It may be added that except in the first 1 or 2 kilometers there is no correlation between the temperature and the direction of the wind.[1]

There is another connection between temperature and pressure that must be noticed. The fall of temperature with height, the "lapse rate," as it is called in England, ceases in latitude 50° N. at about 10.5 to 11 kilometers and the height at which it ceases is commonly denoted by *Hf*. This height varies for England from 7.5 in a deep cyclone to perhaps 13.0 kilometers in an anticyclone. It varies with the surface pressure but it varies much more closely with the pressure at 9 kilometers, the correlation deduced from many hundred observations in England and on the Continent being as high as 0.84. The pressure at any height *hs* is calculated by Laplace's formula from the pressure at the surface and the harmonic mean temperature of the intervening air column, and it has been contended by some that the high correlation is due to this fact. It is necessary, therefore, before seeking further explanation to examine this contention. Keeping the height constant and differentiating Laplace's formula we obtain an equation of the form

$$\delta P_n = A\delta P_o + b\delta T_{n,o} \qquad (1)$$

In this equation a and b are constants which depend upon the height, n kilometers, and the mean values of P and T. Obviously for determining the pressure at a small height it is the term involving a, the surface pressure, that is important, whereas for great heights it is b that matters. Using millibars and degrees C. for units a and b become numerically equal for a height lying between 2 and 3 kilometers, while for a height of 10 kilometers, b becomes five times as great as a. The inevitable relationship shown in equation (1) ensures therefore that there will be a very high correlation between P_n and $T_{n,o}$ unless the height n is small and that the correlation will increase with increasing height; it is apparent also that the coefficient b is essentially positive and that equation (1) must produce a positive correlation. The term T_n is not directly involved in (1) but it is so indirectly because it is used in forming the mean value $T_{n,o}$, but unless the air column is short P_o alone is relatively unimportant. Hence the relation (1) does produce some small correlation; that it is utterly incapable of causing the close connection shown by the observations the following consideration shows.

It has been proved above that the relation $\delta P_n = a\delta P_o + b\delta T_{n,o}$ produces (1) a positive correlation (2) a correlation increasing with the height. The observations show a negative correlation in certain parts which is contrary to (1) and a decreasing correlation from 8 to 13 kilometers which is contrary to (2). The connection between P and T can not therefore be due to Laplace's formula.

The second relationship between pressure and temperature is given by the equation

$$\frac{\delta T}{T} = 0.29\frac{\delta P}{P} \qquad (2)$$

This is the well-known connection between small variations of pressure and temperature that occur when air expands or contracts under circumstances such that it can neither gain nor lose heat. The coefficient 0.29 refers to dry air; for expanding air in which the cooling is producing the condensation of water vapor the value is lower. The requisite condition that there shall be no gain or loss of heat is met with in air not in contact with the surface of the earth that is altering its pressure quickly, say, in a time conveniently measured in hours, If the change takes days, it cannot be called adiabatic, owing to the effect of radiation. Let us assume for the present that no condensation is occurring and that the changes are adiabatic.

The assumption that air follows the rule of changing 10° C. per kilometer change of height is not so far from the truth as might at first sight appear. For the rule applies practically to all descending air since the amount of water that air can contain without spilling it as rain is very small. Secondly the space where vapor is condensing compared with the atmosphere up to, say, 20 kilometers is also small. If we take rain as the index, rain occurs on the average perhaps 1 hour out of 20 and the rain cloud may be about 2 kilometers thick. This gives $\frac{1}{20}$ of $\frac{2}{20}$ or one-half per cent as the space in which the rule of the dry adiabatic rate does not hold. If we take cloud as the index, we may estimate as follows. It has been held that half the sky is on the average covered with clouds and we may take the average thickness as 1 kilometer. This is $\frac{1}{2}$ of $\frac{1}{20}$ or $2\frac{1}{2}$ per cent. Thus even supposing we consider the part of the atmosphere below the 10° kilometer level above the percentage is still only 1 (in 20) or 5 per cent. Strictly the rate for dry air does not quite reach 10° per kilometer, it is 9°.84, but for ordinary air so long as condensation does not occur the value of 10° per kilometer is a sufficiently close approximation.

In equation (2) T must be measured from the absolute zero, but the pressure may be in any units. Taking P in millibars, the value of $0.29\ T/P$ for any height is obtained by substituting the mean value of T and P for that height. The values for England at any exact kilometer height up to 20 so obtained are given below, δP being taken as 1 millibar.

TABLE 2.

Height (km.)...	0	1	2	3	4	5	6	7	8	9	10
C...............	0.08	0.09	0.10	0.11	0.12	0.14	0.15	0.17	0.19	0.22	0.25

Height (km.).........	11	12	13	14	15	16	17	18	19	20
C.....................	0.29	0.33	0.39	0.45	0.54	0.62	0.72	0.85	0.99	1.15

[1] See *Geophysical Memoirs* No. 2, M. O. 210b, p. 45, and *R. Met. S. J.*, Vol. XLVII, No. 197, Jan., 1921, p. 26.

The figures in this table express in another form the fact that dry air rising adiabatically for 1 kilometer will fall 10° in temperature, for if 10 be divided by the decimal giving δT for any height the quotient will express the approximate change of pressure per kilometer in millibars at that height. But the change of pressure may be produced by any means. It is not necessary that the air should rise or fall. Change of position without change of level, if the air comes under a new pressure is, equally efficacious.

The connection between pressure and temperature changes shown algebraically by (2) and set out numerically for each height in Table 2 tends toward a positive correlation increasing with height between P and T. The actual connection as disclosed by some 200 observations is set out below in Table 3.

TABLE 3.

$\delta T_0 = 0.04 \delta P_0$	$\delta T_4 = 0.42 \delta P_4$	$\delta T_8 = 0.44 \delta P_8$	$\delta T_{11} = -0.11 \delta P_{11}$
$\delta T_1 = 0.19 \delta P_1$	$\delta T_5 = 0.46 \delta P_5$	$\delta T_9 = 0.31 \delta P_9$	$\delta T_{12} = -0.29 \delta P_{12}$
$\delta T_2 = 0.34 \delta P_2$	$\delta T_6 = 0.48 \delta P_6$	$\delta T_{10} = 0.14 \delta P_{10}$	$\delta T_{13} = -0.28 \delta P_{13}$
$\delta T_3 = 0.39 \delta P_3$	$\delta T_7 = 0.47 \delta P_7$		

These figures are obtained by the ordinary statistical method. They are, in fact, regression equations between P and T at each height, thus $\delta T_6 = .48 \delta P_6$ means that taking the average of many observations where the pressure at 6 kilometers height is 1 millibar above its average value the temperature will be half a degree (0°.48 C.) above its average. The height is only carried to 13 kilometers because the observations above that height are not sufficiently numerous to give reliable values.

On comparing Tables 2 and 3 it will be seen at once that they do not agree. The observational results shown in Table 3 prove that above 10 kilometers a high pressure is usually associated with a low temperature, over an anticyclonic region the stratosphere is cold, whereas dynamic warming as shown in Table 2 should produce a high temperature, for a high pressure at the ground level remains a high pressure up to about 20 kilometers.

But Table 2 is founded on the assumption that the air found at any level had originally, i. e., before the change of pressure, the temperature and pressure corresponding to that level and this assumption is not warranted. Take the particular values at 6 kilometers as an example. The mean pressure there is 469 mb. and the mean temperature is 248°. If these conditions held and the pressure then rose to 489 mb. the temperature in consequence would rise to 251°. But if instead of a change of pressure occurring at 6 kilometers the pressure both at 6 and 7 kilometers had remained the same, but air for some reason had been forced down from the 7 to the 6 kilometer level, the rise of temperature would be 10°; and since the mean at 7 kilometers is 241°, on reaching the level of 6 kilometers its temperature would be 251°, as before. Similarly for other levels. Thus, without impugning the truth of equation (2) which, since it is a well-established law of physics, we may not do, we can explain the observational results by assuming a vertical motion in the atmosphere dependent on the height and on the distribution of pressure. It is strange that the effect upon the temperature of a small vertical component in the motion of the air should have received so little attention from meteorologists. Hann more than 20 years ago explained the warmth of high Alpine peaks during anticyclonic weather in this way but his suggestions have not been followed up. It is the more curious because the fact that rain is due to the dynamic cooling of an ascending current is emphatically stated in most modern textbooks on meteorology.

It is stated that rain is due to the "cooling" of the air, and yet the cooling of an ascending current is not considered except in the special case when rain is produced. All air that ascends in one place must come down again somewhere else and doubtless there are plenty of air currents with a rapid horizontal component, but with a small vertical component also so that they are blowing at a small angle to the horizontal plane. If this angle be only three minutes of arc its effect on the temperature is equal to that due in a south or north wind to the change of latitude; and yet this small inclination even in a thick, rapidly-moving current would hardly produce a measurable quantity of rain in an hour.

The above statement refers to England where the change in temperature with latitude is small and is the result of a simple calculation.

The change of temperature from Equator to pole is close to 45° C.; that is, 1° C. for 2° of latitude, or for a distance of 222 kilometers. The lapse rate of temperature is 6° per kilometer height and the adiabatic lapse rate is 10° per kilometer for dry air, hence air rising 250 meters will find itself 1° C. colder than its new surroundings. Thus a south wind with an upward gradient of 0.25 in 222, or say 1 in 900, which represents an inclination of less than 4′, will on the average, if no vapor is condensing, find that the two causes for a temperature different to its surroundings just cancel each other and it will show no sign of its place of origin. If then we have vertical motion in the atmosphere, we have a cause of change of temperature at least as powerful as an equatorial or polar wind and it seems certain that currents with an inclination to the horizon much over 4′ are quite common. The rate at which cyclonic rain falls proves this because at the ordinary temperature of the rain-producing strata for central Europe, say 0° C., at 2 kilometers height, the water can not be provided unless there is a fairly rapid upflow of saturated air.

Let us estimate the slope necessary to produce the quite common rate of rain of 2.5 mm. per hour. Take a current of saturated air at 5° C. blowing up a slope of 1 in 100. Consider a cube of 1 cubic meter volume passing up 1 kilometer of such a slope. Using Hann's figures it will fall 0.06° C. in temperature and in consequence condense about 0.025 grams of water. The water will be spread over 1,000 square meters of ground and will provide 2.5×10^{-8} mm. of rain. We have therefore to allow for 10^8 cubic meters per hour passing over each square meter of ground. By assuming the current to be 2 kilometers thick the factor is reduced to $5 \times 10''$ and the velocity of the current required is 50 kilometers per hour. We can hardly take the velocity as much over 50 kilometers per hour or its thickness as more than 2 kilometers; even if we took a thickness of 4 kilometers it would not add much to the rainfall because the upper part would be too cold to carry much moisture. Hence the slope of rain-bringing winds can not be much less than 1 in 100, and the cooling or heating effect of the rise or fall of air in such a wind is some 10 times as great as that due to change of latitude in a north or south wind. Since ascending currents in one place must be compensated by descending currents, bringing down an equal mass of air elsewhere, we have direct proof of vertical motion in the atmosphere sufficient to explain all the temperature anomalies that occur.

The dependence of the temperature upon the pressure can be readily explained if we admit the vertical motion of the air; there is no rigid proof that the explanation is the right one, but it fits in with all the known facts of the case.

If, in the laboratory, we arrange an endless tube with two vertical parts and warm one part, continuous circulation of the air in the tube would set in and the air in the vertical part that is being warmed would be rather warmer than the air in the other parts. But suppose we could perform the experiment in the open air with the vertical branches some few kilometers instead of some few meters in height, the result would be quite different. Unless the heat supplied were very considerable, continuous circulation would not set in. About half the heat supplied to one branch would appear immediately as sensible heat in the other branch and the mean temperatures in the two vertical parts would both rise equally. This result is due to what Sir Napier Shaw calls the resilience of the air. This resilience resists any vertical motion, and is due to the fact that the ordinary lapse rate of temperature is some 4° C. per kilometer less than the dry adiabatic rate.

Let us take, then, an imaginary tube $A\ B\ C\ D$ with its walls impervious to heat, suppose A and C to be vertical parts of a few kilometers length and B and D to be horizontal branches of 50 or 100 kilometers, and suppose the air inside to be at the mean atmospheric temperature for the corresponding height. Suppose now that the air is compelled by some external force to shift by 250 meters round the tube in the direction $A\ B\ C\ D$ so that the air at A originally will come to a, a point 250 meters above A, and the air at C originally to c, a point 250 millimeters below C. The result on the temperatures will be that save near the corners the temperature in the column A will be 2° C. below that in the column C for points at the same height because the lapse rate being 6° per kilometer and the dry adiabatic rate 10° per kilometer, the air at any point A on the rising side will be 1° cooler than before and at any point C on the falling side it will be 1° hotter. Now suppose the force causing the displacement to cease; the air in the column C being the warmer will rise and the initial condition of the same temperature at the same height on both sides will be restored. It is not necessary to postulate any force at all. Starting from the initial conditions, if by any means the air in one vertical branch becomes hot or cold, the resulting circulation which sets in under gravity continues until equality of mean temperature in the two vertical branches is attained.

The force that has been supposed to act may well be due to the distribution of pressure and it has been shown that if a suitable external force is acting on the air differences of temperature at the same level may be maintained but that if no force save gravity is acting, heat applied at a point A will not have the sole effect of warming the air at A but will, owing to the circulation that will ensue, also warm the air at the same level within a moderate distance of A.

If A be near the ground, vertical circulation can not readily occur and we find, as a matter of fact, that near the ground there is no appreciable correlation between pressure and temperature, but in the upper half of the troposphere, where vertical motion is least impeded by proximity to the boundaries, the correlation is closest.

Now suppose a tube of flow like $A\ B\ C\ D$ to be moving with the general air current and to be so placed that its horizontal branches more or less coincide in direction with the line of the isobars. There is not likely to be any appreciable force due to the pressure distribution to cause circulation. Hence, as already shown, there should be equality of temperature for points at the same height. That is to say, since the points are approximately over the same isobar, at points at the same pressure, and this is the first requirement to produce a high correlation between pressure and temperature.

Next suppose our imaginary tube of flow to lie with its horizontal branches more or less at right angles to the isobars or to the current of air in which it is moving. There is now a pressure gradient along both horizontal branches and it seems quite likely that integrating round the tube there may be an effective force causing a shift of air. Suppose it to cause such a shift in the direction $A\ B\ C\ D$; then, as has been shown, the air in the vertical branch A will be colder than that in the vertical branch C and will continue colder while the force causing the shift is in action. Suppose A to lie inside so that it is nearer the cyclonic center than C. Then we have lower temperature combined with lower pressure and hence a positive correlation.

If we could experiment with an actual tube, it would not matter in what part of the tube the force was applied, but the tube is only a convenient mathematical conception. If, however, the circulation will occur in the tube, much more will it occur in the free atmosphere, and it is obvious from what has been said that if a force acts horizontally in the atmosphere so as to shift air from a region A to a region B, A and B not being too near the earth's surface, the result is a tendency to cool the air under A and over B and to warm the air over A and under B. This follows because the deficiency of air at A caused by the flow must be made good and the excess at B disposed of. Remembering the great disproportion between the vertical and the horizontal scale that any representation of a cyclone on paper must present, we see that the deficiency as well as the excess would naturally be compensated by a vertical component of the air's motion.

Now the distribution of temperature, we have to explain, is a high temperature in the stratosphere over a cyclone and a low temperature in the troposphere, most marked in the upper part; that is to say, a high temperature above 10 kilometers, a low temperature occurring with very great certainty from 4 to 8 kilometers and a low temperature, but not so certainly, from 1 to 4 kilometers. These conditions, which many hundred observations in Europe have shown to exist beyond dispute, are fully explained dynamically if we suppose the upper winds to produce a sort of sucking action on the air at about 9 kilometers height, so as to take the air from the upper part of the troposphere; for this motion, as already shown, produces the required temperatures. This also explains the fall in height of the boundary between the troposphere and stratosphere which occurs over every well-marked cyclonic area, for as the column of air falls its lapse rate remains comparatively unaltered, all the temperatures being raised by about the same amount, so that the usual inversion at the boundary still remains an inversion, but at a higher temperature and lower level.

The statement made above with regard to a cyclonic area refers with equal truth to an anticyclonic area if the terms "high" and "low" be interchanged. The horizontal flow of air at 8 or 10 kilometers height toward an anticyclone will press up the upper boundary of the troposphere and cause cold above in the stratosphere. It will also press down the air under the locality where it ends and cause warmth in the troposphere.

The only difficulty I see in this explanation is the difficulty of assigning a reason for the flow of air at 8 to 10 kilometers from the cyclonic to the anticyclonic area. This is the height of the strongest winds, and it is easy to ascribe the flow in general terms to the geostrophic and centrifugal action of the wind, but that does not carry us much farther. If it is correct, it means that cyclones are generated in the upper part of the troposphere by the general circulation of the atmosphere and spread downward. Also that there is a slight outflow of air from the cyclone above; it need only be slight, just as there is a slight inflow below near the ground.

A correct theory of the formation and propagation of cyclones must be able to account for the well-marked distribution of temperature in the upper air that accompanies them and the temperature is almost certainly due to dynamic heating and cooling. The changes of temperature accompany the changes of pressure and are large from day to day, far larger than would be possible if they were due solely or chiefly to radiation. It is natural to look to the direction of the wind to account for changes of temperature, but the statistical evidence is perfectly distinct in showing that the direction of the wind, save quite close to the earth, has only a trifling effect upon the temperature. Above 2 kilometers there is no appreciable correlation between the south to north or west to east components of the wind and the temperature. This is the case if the actual surface wind, the gradient wind, or the drift of the balloon which carries the instruments be used. Doubtless, as Capt. C. K. M. Douglass urges (R. Met. S. J., Vol. XLVII, No. 197, p. 23), it is the place of origin of the air, not its temporary direction that matters, but in view of the absence of correlation between wind direction in the upper air and temperature it does not seem possible to me that cyclones should be caused by the action of polar and equatorial currents. On the other hand there can be no doubt that the mild winters of western Europe are due to the prevalent southwest and west winds coming from the warm waters of the north Atlantic.

In the suggested explanation of the correlation between pressure and temperature nothing has been said about the time requisite for the adjustment. If the explanation is to be feasible, the time required must be comparatively short; otherwise radiation would prevent the changes of temperature from being adiabatic. If we neglect frictional resistances, it can be shown by elementary dynamical considerations that equalization of temperature between places 200 kilometers apart would take about an hour. The time required varies as the square root of the distance, so that the equalization between two places on the ordinary weather chart is only a matter of an hour or two, in which time radiation would not have much effect. But the assumption that frictional resistances may be neglected is certainly a large one owing to the eddy viscosity of the atmosphere. However, the gradient wind appears to adjust itself with considerable rapidity to the distribution of pressure notwithstanding the eddy viscosity, so perhaps the time is not greatly increased by the same cause. But the retardation due to eddy viscosity will vary as the distance, so that for large distances it may be very considerable. This may explain why differences of mean temperature exist in winter between, let us say, England and eastern Europe at a few kilometers height, though it may be noted that such differences are far smaller than those found at ground level.

AVERAGE FREE-AIR WINDS AT LANSING, MICHIGAN.

C. L. RAY, Observer.

[Weather Bureau, Lansing, Mich., Oct. 14, 1922.]

The first pilot-balloon ascension at this station was made June 10, 1919, and flights have been made daily since that time, except when impossible through inclemency of the weather. Flights were made at 7 a. m. and 3 p. m. until August, 1921. Beginning with the flight of August 1, the morning ascensions were discontinued, and the single flight daily at 3 p. m. has been made since that time.

The results set forth in this paper have been based on the flights made during the three-year period, June 1919–May 1922, inclusive. The number of flights obtained during that time, and listed by seasons and altitudes, follows:

TABLE 1.—*Number of pilot-balloon ascensions, June 1919, to May, 1922, inclusive.*

Altitude.	Spring.	Summer.	Autumn.	Winter.	Annual.
m.					
Surface	364	420	366	324	1,474
250	364	420	366	324	1,474
500	344	414	353	286	1,397
750	323	401	326	242	1,292
1,000	307	394	290	213	1,204
1,500	264	359	254	170	1,047
2,000	231	313	226	143	913
2,500	194	266	177	127	764
3,000	164	235	148	110	657
3,500	136	190	116	87	529
4,000	117	170	94	76	457
4,500	103	152	66	56	377
5,000	85	136	56	40	277
6,000	52	100	34	27	213

The percentage of winds from various directions over this three-year period is shown in Table 2, and as will be noted shows over 50 per cent of the surface winds with a south component and more than 56 per cent with a west component. At 4,000 and 6,000 meters elevation the preponderant direction lies between west and northwest, and slightly favoring northwest. The detailed percentages are as follows:

TABLE 2.—*Percentage frequency of winds observed from various directions.*

Meters.	N.	NNE.	NE.	ENE.	E.	ESE.	SE.	SSE.	S.	SSW.	SW.	WSW.	W.	WNW.	NW.	NNW.
Surface	6	4	5	3	3	3	5	5	9	10	11	8	10	6	8	4
1,000	5	5	4	2	3	2	2	3	5	6	10	11	16	10	11	5
2,000	6	3	4	2	2	2	2	1	2	4	8	12	18	14	12	8
4,000	4	3	4	2	1	1	1	2	2	4	8	7	17	19	16	9
6,000	6	1	4	1	0	3	1	2	1	4	6	8	15	20	21	7

The information contained in this table has been used in the graphical representation (fig. 1), which shows probably to better advantage the results obtained. Above 2,000 meters west to northwest winds generally prevail.

In Table 3 are given the mean free-air winds for the different seasons and the mean annual directions and velocities. Southwest winds prevail at the surface during the spring, summer, and autumn months, giving place to a west direction in the winter season. All surface velocities are close to three meters per second

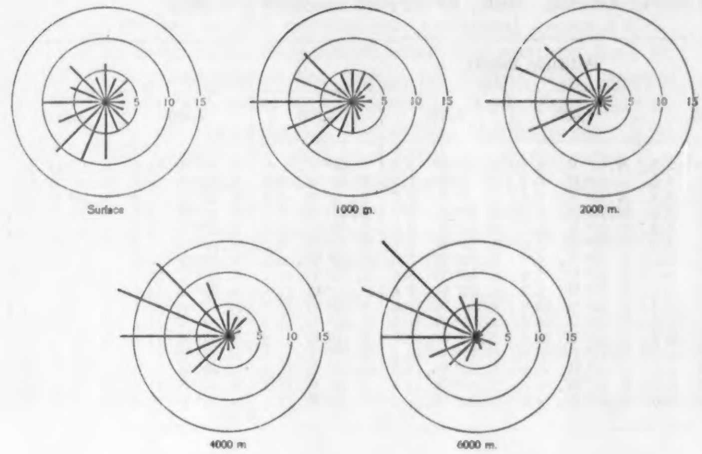


FIGURE 1.—Percentage frequency of winds from various directions at different levels above Lansing, Mich.

with a slightly greater speed during the spring months. At 250 meters, the winds have shifted quite definitely in a clockwise direction and velocities average two and a half times greater than at the surface. Above 1,500 meters a south component is in no instance observable in the means and the winds are consistently west to northwest. Velocities are greatest in the winter months, and at the 6,000-meter elevation the average reaches 27.7 meters per second, as compared with the summer mean of 12 m/s. at that level. In Figure 2 the mean seasonal wind directions and velocities have been plotted and the contrast of winter and summer velocities is shown, as also the similarity of autumn and spring velocities. A glance at the graph of directions shows particularly the more consistently west component during the autumn months, with only slight deviation above 1,500 meters from a due west direction. In the other seasons the north component is more generally present, while in no case above 1,500 meters, as stated before, is there any close approach to a south component.

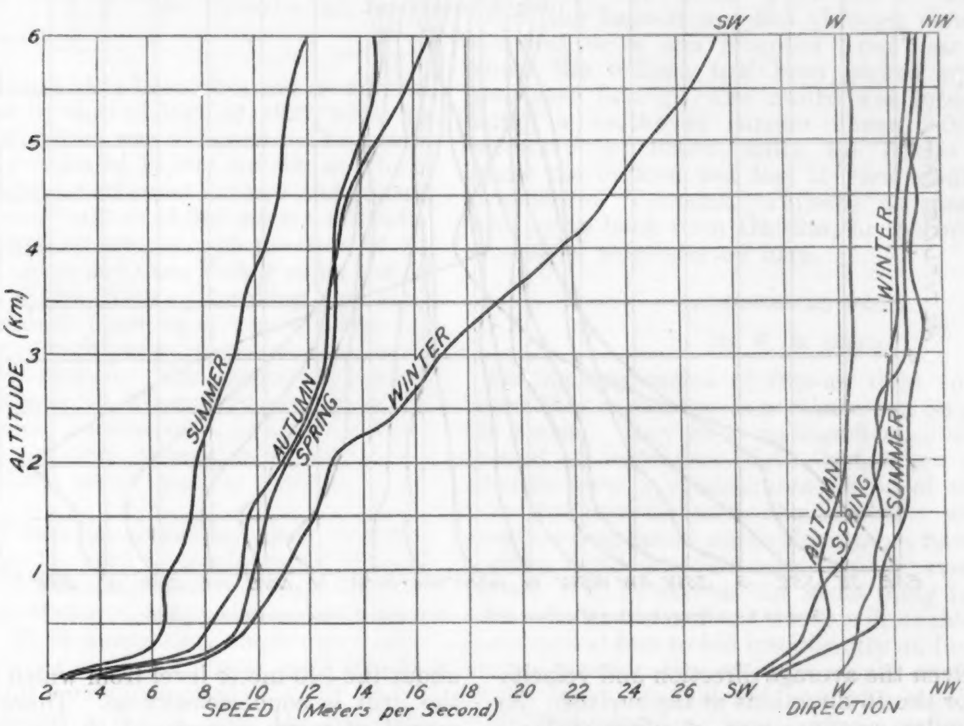


FIGURE 2.—Mean seasonal wind directions and speeds above Lansing, Mich.

TABLE 3.—*Mean free-air winds at Lansing, Mich., June, 1919, to May, 1922, inclusive.*

[Altitude, 262.9 m.; latitude, 42° 44'; longitude, 84° 26'.]

Altitude.	Spring.		Summer.		Autumn.		Winter.		Annual.	
	Direction.	Velocity.	Direction.	Velocity.	Direction.	Velocity.	Direction.	Velocity.	Direction.	Velocity.
m.		*m. p. s.*		*m. p. s.*		*m. p. s.*		*m. p. s.*		*m. p. s.*
Surface	S. 55° W.	3.6	S. 63° W.	2.4	S. 56° W.	2.9	S. 88° W.	3.3	S. 66° W.	3.1
250	S. 70° W.	7.8	S. 80° W.	5.8	S. 76° W.	7.6	N. 87° W.	8.0	S. 80° W.	7.3
500	S. 77° W.	9.2	N. 73° W.	6.3	S. 86° W.	8.2	N. 85° W.	9.5	N. 89° W.	8.3
750	S. 79° W.	9.6	N. 73° W.	6.3	S. 79° W.	9.0	N. 83° W.	10.4	W.	8.8
1,000	S. 89° W.	9.8	N. 70° W.	6.4	S. 82° W.	9.4	N. 77° W.	10.8	N. 82° W.	9.1
1,500	N. 83° W.	10.3	N. 64° W.	7.3	S. 89° W.	9.8	N. 73° W.	12.2	N. 78° W.	9.9
2,000	N. 73° W.	11.0	N. 60° W.	7.8	N. 89° W.	10.8	N. 73° W.	12.8	N. 74° W.	10.6
2,500	N. 73° W.	12.0	N. 62° W.	8.4	N. 89° W.	12.0	N. 70° W.	15.5	N. 74° W.	12.0
3,000	N. 64° W.	13.1	N. 58° W.	9.1	N. 83° W.	12.9	N. 68° W.	16.8	N. 68° W.	13.0
3,500	N. 64° W.	13.7	N. 58° W.	9.7	N. 85° W.	13.6	N. 65° W.	18.8	N. 68° W.	14.0
4,000	N. 64° W.	14.9	N. 63° W.	10.2	N. 85° W.	15.0	N. 66° W.	21.7	N. 70° W.	15.4
4,500	N. 66° W.	15.4	N. 58° W.	10.3	N. 86° W.	15.7	N. 61° W.	23.5	N. 66° W.	16.2
5,000	N. 64° W.	16.0	N. 61° W.	11.1	N. 84° W.	16.4	N. 57° W.	24.6	N. 66° W.	17.0
6,000	N. 58° W.	16.8	N. 57° W.	12.0	N. 84° W.	18.5	N. 54° W.	27.7	N. 63° W.	18.8

TABLE 4.—*Average annual direction and speed of free-air winds, Lansing, Mich., for different directions at surface.*

Surface.	Altitude, meters.							
	250	500	750	1,000	2,000	3,000	4,000	5,000
N. 2.3	N. 12° E. 4.9	N. 3° E. 5.3	N. 3° W. 5.8	N. 11° W. 6.3	N. 15° W. 9.2	N. 19° W. 11.6	N. 39° W. 14.5	N. 33° W. 18.1
NNE. 2.7	N. 27° E. 6.0	N. 32° E. 6.3	N. 24° E. 6.5	N. 18° E. 6.2	N. 6° W. 7.0	N. 23° W. 9.2	N. 22° W. 11.5	N. 26° W. 12.4
NE. 2.8	N. 46° E. 6.5	N. 49° E. 7.0	N. 17° E. 6.8	N. 40° E. 6.6	N. 3° E. 7.7	N. 8° W. 8.8	N. 29° W. 11.3	N. 28° W. 12.7
ENE. 2.5	N. 73° E. 5.8	N. 81° E. 6.4	N. 76° E. 6.0	N. 73° E. 6.5	N. 19° E. 6.4	N. 17° W. 7.4	N. 22° W. 9.9	N. 30° W. 12.1
E. 2.6	S. 83° E. 5.9	S. 79° E. 6.7	S. 71° E. 6.3	S. 60° E. 6.2	N. 48° E. 6.0	N. 76° W. 7.5	N. 66° W. 9.4	N. 68° W. 10.6
ESE. 2.2	S. 63° E. 5.8	S. 50° E. 6.0	S. 42° E. 5.8	S. 32° E. 5.9	S. 78° W. 6.6	N. 63° W. 6.5	N. 79° W. 8.9	S. 85° W. 9.7
SE. 2.6	S. 26° E. 6.1	S. 19° E. 6.7	S. 13° E. 6.9	S. 12° E. 6.7	S. 53° W. 7.6	S. 81° W. 9.1	N. 85° W. 11.3	S. 89° W. 13.2
SSE. 2.8	S. 11° E. 7.7	S. 2° W. 8.6	S. 14° W. 8.5	S. 35° W. 7.9	S. 69° W. 8.6	S. 74° W. 11.2	S. 85° W. 13.2	N. 81° W. 14.4
S. 3.3	S. 23° W. 7.6	S. 29° W. 9.4	S. 37° W. 9.5	S. 45° W. 9.7	S. 62° W. 9.6	S. 74° W. 11.8	S. 78° W. 13.9	N. 88° W. 15.7
SSW. 2.9	S. 46° W. 8.4	S. 57° W. 9.8	S. 63° W. 10.7	S. 64° W. 10.8	S. 80° W. 11.6	N. 89° W. 13.7	N. 76° W. 16.7	N. 71° W. 18.1
SW. 3.0	S. 60° W. 8.6	S. 70° W. 9.6	S. 69° W. 10.3	S. 73° W. 10.6	N. 85° W. 11.5	S. 88° W. 13.0	N. 84° W. 15.1	N. 81° W. 17.0
WSW. 3.1	S. 77° W. 8.4	S. 85° W. 9.3	S. 89° W. 10.2	N. 89° W. 10.6	N. 80° W. 12.7	N. 70° W. 15.3	N. 66° W. 17.2	N. 48° W. 18.6
W. 3.5	N. 85° W. 7.8	N. 82° W. 9.3	N. 79° W. 10.3	N. 79° W. 10.9	N. 71° W. 12.2	N. 70° W. 15.6	N. 59° W. 17.9	N. 63° W. 19.7
WNW. 4.0	N. 61° W. 7.9	N. 60° W. 9.5	N. 59° W. 9.2	N. 58° W. 9.9	N. 52° W. 13.0	N. 50° W. 16.6	N. 52° W. 19.2	N. 49° W. 20.9
NW. 3.3	N. 39° W. 6.9	N. 40° W. 8.4	N. 42° W. 8.8	N. 39° W. 9.5	N. 49° W. 13.6	N. 48° W. 17.1	N. 44° W. 20.3	N. 52° W. 22.2
NNW. 3.2	N. 23° W. 5.9	N. 23° W. 6.8	N. 29° W. 7.6	N. 30° W. 8.6	N. 34° W. 11.5	N. 40° W. 15.1	N. 55° W. 18.6	N. 54° W. 20.2

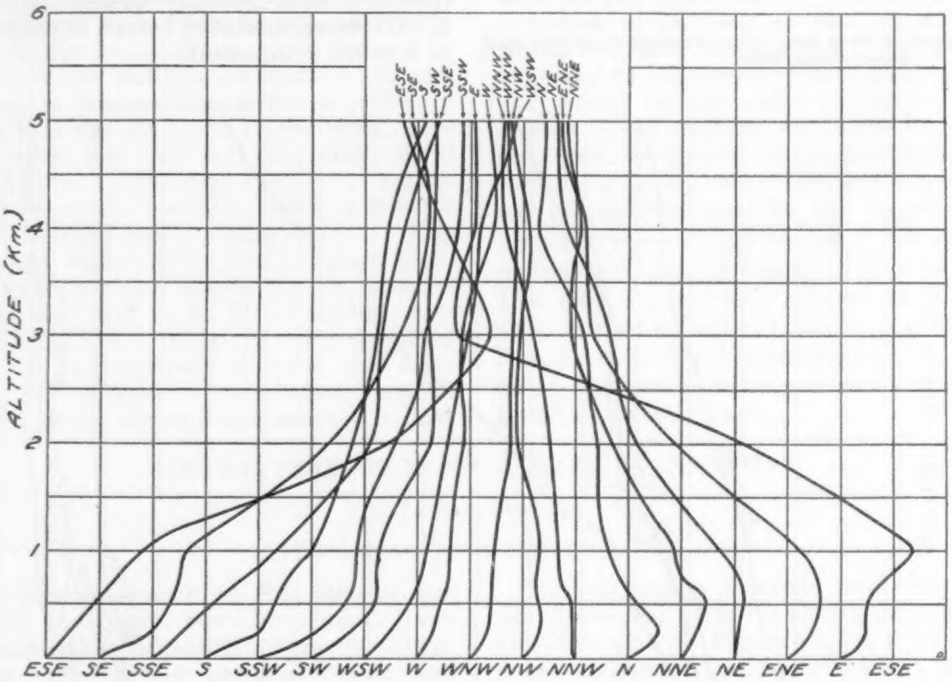


FIGURE 3.—Average turning of various surface winds with altitude above Lansing, Mich.

In Table 4 are given the average direction and velocity at various levels for the 16 directions at the surface. As shown also by similar computations at other stations the increase in velocity from the surface to about 500 meters is approximately the same for all directions. In the upper levels, however, the easterly winds do not reach the velocities attained by the westerlies. Easterly surface winds in most cases shift to west with altitude, the shift occurring frequently between 1,000 and 2,000 meters. Through this shift the velocities are generally small and after reaching a west or northwest current do not usually attain a speed of a wind that has been consistently west from the surface up.

In Figure 3 the tabulated data have been plotted and the relative differences in direction aloft for different surface directions are shown. In the case of surface winds with an east component, the number of flights in several instances is few, and the average direction obtained is probably not entirely dependable. Winds with a surface south component all show a clockwise movement with altitude and as a rule reach a west-southwest direction at about 2,000 meters. Winds with a north-surface component also follow a clockwise direction to about the 500-meter level from which approximate point the drift is counterclockwise. There is a more or less persistent north component to the highest levels, however, the average at 6,000 m. for all winds with a north-surface component being about north-northwest.

TABLE 5.—*Number of flights with different surface directions.*

Meters.	N.	NNE.	NE.	ENE.	E.	ESE.	SE.	SSE.	S.	SSW.	SW.	WSW.	W.	WNW.	NW.	NNW.
250	80	58	73	45	45	42	61	65	110	126	139	105	144	77	106	49
500	74	53	66	42	42	42	56	61	108	124	136	100	137	67	101	45
750	68	50	64	39	41	39	56	59	102	112	128	90	119	56	94	39
1,000	64	46	59	36	40	39	51	54	98	107	122	85	107	48	87	38
2,000	49	36	50	32	34	30	39	45	71	78	95	64	59	26	61	26
3,000	33	28	41	23	26	22	28	36	53	63	66	38	41	16	40	18
4,000	28	18	31	18	22	17	21	28	41	32	42	21	23	10	26	16
5,000	18	12	23	16	18	14	18	19	28	21	30	11	15	7	13	8

A series of flights made between January 24 and 30, 1922, was unusual because of the presence of an east component at the surface in each instance, and because of the comparatively high altitudes attained. The pressure was generally high over the country, with a center of 30.80 inches at Green Bay, Wis., on the 24th, and the tempera-

ture at that point −20° F. The only low area present was 30.10 inches in the northwest, centered around Calgary. The high area continued over the eastern half of the country throughout the series of flights, the center moving over the Lakes and thence to New York State. On the 29th, the sixth day of the series, the high area had backtracked apparently and had built up again over the Lakes and Michigan, with a center of 30.70 inches at Sault Ste. Marie. At this time storms had formed in the southern Rockies, with a low center of 29.40 inches at Denver. A summary of the series follows:

TABLE 6.—*Balloon flights, January 24–30, 1922.*

	Jan. 24.	Jan. 25.	Jan. 26.	Jan. 27.	Jan. 28.	Jan. 29.	Jan. 30.
Surface	NNE. 2.2	SSE. 2.7	E. 2.7	NE. 2.7	NNE. 3.1	ENE. 2.7	ESE. 2.2
1,000	NNE. 2.9	SSE. 6.4	SE. 4.7	ESE. 7.5	ENE. 6.7	E. 7.1	SSW. 5.0
2,000	NNW. 8.4	WSW. 4.0	S. 1.3	ENE. 3.2	ENE. 5.6	NE. 6.4	SSW. 9.0
3,000	NNW. 11.2	W. 4.2	SW. 4.0	E. 2.0	NE. 4.1	ENE. 5.0	SSW. 11.8
4,000	NW. 16.2	WNW. 6.3	WSW. 5.0	SW. 1.0	NNE. 3.2	NNW. 2.0	SW. 11.3
5,000	WNW. 24.0	W. 6.0	SSW. 4.5	NNW. 2.0	NNW. 7.0	N. 5.2	SW. 11.8
6,000	WNW. 27.5	WNW. 5.3	SSW. 3.5	....	NNW. 12.3	NNW. 12.0	....
7,000	....	NW. 4.6	WSW. 4.2	....	NNW. 16.0	NW. 22.9	....
8,000	....	NW. 6.3	....	....	WSW. 12.0	WNW. 25.7	
9,000	....	NW. 9.0	....	....	NW. 10.0	WNW. 34.5	....
10,000	....	WNW. 15.2	....	....	....	....	....

Flights of great altitude have been obtained on several occasions, as instanced by that of May 12, 1922, when an altitude of over 15,000 meters was obtained. The winds were light until an elevation of 12,000 meters, at which point the balloon entered a northwest current and velocities increased steadily to 27 m/s. at 15,900 meters' altitude. The weather map showed an area of high pressure of 30 inches over the Great Lakes and Ohio Valley and a low of 29.50 inches at North Platte, Nebr. Reaching high altitudes is largely dependent upon light winds, which in turn usually result from a high-pressure area centered over or near the observing station. The greatly increased velocities indicated above 10 kilometers are probably faulty in some instances, because of a leaking balloon, although many recent double theodolite observations show that accurate results are obtained as a rule up to 15 kilometers, at least.

Several flights with extreme velocities have been recorded. On November 18, 1919, a maximum of 58 m/s. was observed near the 6,000-meter level. A high velocity was reported also from Madison, Wis.; the weather map showed a low area of 29.55 inches over the Great Lakes and a high of 30.40 inches at North Platte, with closely placed isobaric lines and a steep gradient.

On December 17, about a month after the instance noted above, the highest velocity ever recorded at Lansing was obtained, 83 m/s. from the northwest at about 7,000 meters' altitude. A large increase in velocity with altitude was also observed at Madison, Wis., but the balloon was followed only to 2 kilometers where the wind was NW. 26 m/s. The pressure was high with a crest of 30.50 inches at St. Paul and there was a low area of 30 inches moving off the Atlantic coast.[1]

Light winds are recorded more or less frequently during the summer months. On July 4 and 5, 1921, with a high pressure of 30.20 inches over the Great Lakes and down through Illinois, Missouri, and Oklahoma, flights of 9,000 m. and 6,000 m., respectively, were obtained and very light winds prevailed throughout, averaging 3 and 4 m/s. On July 13, 1921, a high pressure of 30.30 inches over the Great Lakes and small gradients gave light air currents up to 10,000 meters, where the balloon was lost.

[1] For more detailed discussion of this high wind see MO. WEATHER REV., 47; 853–854.

An interesting device has been employed at this and several other upper-air stations. A tag is attached to the balloon with request that finder return it, together with any information as to where and when found, was it seen falling, and finder's name and address, so that return may be acknowledged. The tag is of lightweight cardboard, measuring about 2″ by 3″, the additional weight being considered in calculating the total lift. By means of the tag it is possible to obtain interesting data as to the course of the winds after the balloon has been lost to view through clouds or distance. About 10 per cent of the tags are returned, the percentage being greater than that during summer and less in winter. While most of the returns are from points in Michigan, indicating that the balloons generally burst before going any great distance or altitude, there have been a number of reports from Canadian points and from near-by States, West Virginia, Ohio, and Pennsylvania.

One flight of particular interest was made on December 28, 1919. The winds were WNW. at 7,000 meters where the balloon was lost through distance. The tag attached to it was returned from near Rutland, Vt., where the balloon had been picked up. It had not been seen falling. The return was interesting as indicating a southwest current above 7,000 meters, the necessary conclusion, since the course of the winds where the balloon was lost to view would have carried it south of Vermont. Perhaps as many as 25 tags have come back from Ontario, in the brief period since ascensions were started here.

ADDITIONAL NOTE.

By W. R. GREGG.

In the application of free-air data to aviation it is found that increasing importance can be given to *resultant* winds. They have no significance whatever in the case of an individual flight, but, when a regular daily schedule over a considerable period of time, a year for example, is considered, the resultant winds determine what cruising speed an airplane must have in order that a given flight schedule may, on the average, be maintained. Or, to express the same thing in another way, a knowledge of resultant winds will enable a commercial aeronautical firm to bid intelligently on furnishing regular service between two or more points on the basis of the help or hindrance that will, on the average, be experienced from "following" or "head" winds, respectively. Hence it seems appropriate to include resultant wind values in any statistical study of free-air winds. This I have done for Lansing, using for this purpose the figures given in Table 4 of Mr. Ray's paper. The results are given in Table 7, which, for purposes of comparison, contains also wind resultants, previously published,[2] for stations not far distant from Lansing.

TABLE 7.—*Annual resultant winds (m. p. s.) at four stations in North Central United States.*

Altitude above station.	Lansing, Mich.	Royal Center, Ind.	Drexel, Nebr.	Ellendale, N. Dak.
m.				
Surface	S. 72° W. 0.9	S. 53° W. 1.8	S. 37° W. 0.9	N. 48° W. 1.3
250	S. 69° W. 2.6	S. 53° W. 3.5	S. 50° W. 1.5	N. 68° W. 1.8
500	S. 81° W. 3.9	S. 60° W. 4.6	S. 65° W. 2.2	N. 74° W. 2.3
750	S. 84° W. 4.4	S. 65° W. 5.5	S. 74° W. 3.2	N. 75° W. 3.1
1,000	S. 89° W. 5.0	S. 72° W. 6.4	S. 84° W. 4.6	N. 76° W. 3.9
2,000	N. 71° W. 7.8	S. 77° W. 7.8	N. 89° W. 8.1	N. 76° W. 7.5
3,000	N. 69° W. 10.6	S. 83° W. 10.0	N. 86° W. 11.3	N. 75° W. 11.2
4,000	N. 65° W. 13.1	S. 83° W. 11.4	N. 83° W. 13.2	N. 77° W. 12.5
5,000	N. 63° W. 14.5	....	N. 76° W. 14.4	....

As shown in the table, resultant speeds at these four stations agree rather closely, except in the lower levels, where they are somewhat greater at Lansing and Royal Center than at Drexel and Ellendale. A point well brought out by the figures is the latitudinal variation in resultant direction, the north component increasing with latitude and being quite pronounced at Ellendale, where it persists at all altitudes. At Royal Center a south component is found, although it is small in the upper levels. There are, of course, seasonal variations, the north component being strongest in winter, and weakest in summer. Seasonal values have not yet been computed for Lansing, but they have been published for the other three stations.[2]

[2] An Aerological Survey of the United States, Part I. Results of observations by means of kites, Mo. WEATHER REV. Supplement No. 20, Table 4, 1922.

RELATION OF CROP YIELDS TO QUANTITY OF IRRIGATION WATER IN SOUTHWESTERN KANSAS.

By J. B. KINCER.

[Review of Bulletin 228, Kansas Agricultural Experiment Station.]

While Kansas is one of our leading agricultural States, the more western portion usually receives rather scanty rainfall. The 20-inch annual isohyet extends across the State in a north-south direction about 60 miles from the western border, which means that some 7,000,000 acres of land receive less than 20 inches of precipitation annually. This amount of rainfall is usually considered about the minimum necessary for successful farming under ordinary cultural methods and, consequently, in extreme western Kansas, farming is more or less precarious from the standpoint of returns, unless special methods are employed for artificially supplying or conserving soil moisture.

Up to the present time irrigation has not been practiced in this section to any great extent, although nearly 100,000 acres are so treated, about 80 per cent being in Finney and Kearny Counties through which the Arkansas River flows. Owing to the existence of large supplies of readily available underground water, however, especially in the southwestern portion of the State, it is quite likely that irrigation at some future time may be practiced very extensively. In view of this, the Kansas Agricultural Experiment Station is maintaining at Garden City, Finney County, a branch station chiefly for experimental purposes to secure information applicable to both present and prospective irrigation problems.

There are two questions of primary interest to every irrigation farmer: (1) The kind of crops best suited to irrigation farming, and (2) the most economical amounts of water to apply. To aid in answering these a series of experiments was started by the branch station at Garden City in 1914 and continued for five years, under the supervision of Mr. George S. Knapp, superintendent. The results are set forth in Bulletin 228, Agricultural Experiment Station, Manhattan, Kans., and may be briefly reviewed as follows:

Experiments were conducted with seven crops, including milo, kafir, sumac, Sudan grass, wheat, oats, and barley, grown in duplicate series on plats containing one-twentieth of an acre. Each crop was grown on four plats, designated, "A," "B," "C," and "D," each of which received a different amount of water. All plats were irrigated during the winter, and in addition, the A plats were irrigated sufficiently during the summer to maintain the moisture content of the soil at about 20 per cent; the B plats at about 16 per cent, and the C plats at about 12 per cent. The D plats were not irrigated during the growing season. Because of the seasonal variation of rainfall and a lack of knowledge concerning the amount of water actually required by the crop under test, the moisture content of the soil was determined at intervals as a basis for the application of water. Whenever the moisture content dropped a few points below the predetermined condition for a given plat, water was applied in sufficient quantity to raise the moisture content a few points above the fixed amount. From 2 to 4 inches of water were applied at each irrigation.

Five-year average productions for milo grain were: Plat A, 53.7 bushels; B, 47.3; C, 40.7; and D, 15.3. While each increase in the amount of water showed a definite increase in yield, the greatest difference was between the D and C series, where an increase of 4.1 inches, or 47 per cent of the amount of water applied increased the yield 22.4 bushels, or 146 per cent.

In the case of kafir, the amounts of water required to maintain the soil moisture were almost the same as for milo, but the yields were not so large and showed a smaller range on the different plats. The yields in like serial order were 33.7, 29.6, 23.8, and 13.3. While these results in the main agree with those for milo, there was a less definite response with increased application of water, from which it appears that kafir is not so productive a crop as milo to raise under irrigation, unless produced for forage as well as grain.

In general, the response of sumac to water was about the same as for milo and kafir, although the conclusions are quite different, because this crop is used primarily more for forage than for grain. There was a gradual increase in the amount of forage, but the difference was not great in the three plats receiving water during the growing season. Throughout the experiment, it was observed that the sorghum crops most plentifully supplied with water invariably matured earliest. This appeared to be due to the plants becoming dormant when moisture was deficient and resuming growth when water was applied, while those receiving sufficient moisture made continuous growth and consequently matured earlier.

One of the most striking results with Sudan grass was its failure to respond significantly to increased quantities of water in both seed and stover. There was a slight increase in the yield of stover, but it was very small compared with the amount of water used. It might be supposed that the lack of response to increased water indicates a small water requirement of the crop, but at the same time more water was necessary to maintain the soil moisture at the required degree than for any other sorghum crop in the experiment, which would indicate that it took up water more rapidly than the others. The grass was planted in rows, however, and it is probable that had it been drilled and harvested as a hay crop, the yield of hay would have been much larger and there would probably have been a wider variation for the different plats.

In the case of wheat, there was in general an increase in yield with increased application of water, but there were large variations in yield from year to year, notwithstanding the soil moisture was maintained at an approximately uniform degree. Mr. Knapp concludes from this that wheat yields were influenced nearly as much by gen-

eral weather conditions during the growing season as by soil moisture; that no amount of water would insure good yields in unfavorable years; that increasing the amount of water has little effect on yield, and that very little is to be gained by the application of more than 10 inches of irrigation water. The five-year averages show for the D plats, 13.4 bushels per acre; C, 19.3; B, 19.1; and A, 21.8. The results with oats and barley corresponded in general with those for wheat.

It is of interest to note the amount of irrigation water required to maintain the respective plats at the predetermined moisture content and the relation these amounts bore to the rainfall and winter irrigation. The latter was governed by soil conditions and varied somewhat from year to year, but in general amounted to about 8 inches, that is, the depth to which the water applied would have covered the land if there had been no percolation. The five-year average required during the growing season to maintain the soil moisture at 12 per cent was about 2.5 inches for the sorghums and about 2 inches for the grains. For the 16 per cent moisture plats, the requirement was about 7 and 7.5 inches, respectively, and for those maintained at 20 per cent, about 13 and 14 inches.

The amounts required in individual years, however, varied greatly from these averages, but they show a very close relation to the amount of winter precipitation. The period covered is so short that a statistical correlation between the several variants could not be considered of much significance, but the relation shown between the amount of irrigation required during the growing season and the precipitation during the preceding fall and winter months is remarkable and the lack of relation between the irrigation water and summer rainfall is surprising. If we combine the three sorghum crops, milo, kafir, and sumac, and count the total number of plats in a given series of each, we have 15 values for comparison. In this case the relation, for example, between the respective B plats, maintained at a moisture content of 16 per cent, and the total precipitation for the period from October to March, inclusive, is represented by the correlation coefficient −0.86. On the other hand, the coefficient between the amount of water applied to these plats and the rainfall during the growing season, April to August, inclusive, is zero, while little or no relation appears to exist between the irrigation water applied in winter and that required during the growing season.

As indications of these relations and lack of relations the following data may be considered: The total winter rainfall October to March, inclusive, for the respective years was 1914–15, 5.5 inches; 1915–16, 3.7 inches; 1916–17, 2.1 inches; 1917–18, 3.8 inches; 1918–19, 9.7 inches. The corresponding summer rainfalls were 18.4, 11.5, 13.2, 9.4, and 8.0. The amount of summer irrigation required to maintain the milo plat at 16 per cent moisture content was 3.4, 9.1, 13.4, 8.8, and 2.6, respectively. It will be noted that for the year 1918–19 when the fall and winter precipitation was 9.7 inches the C plats required no summer irrigation and 2.6 inches were all that was necessary to maintain the B plats at 16 per cent moisture content for milo. On the other hand, the year preceding had only 3.8 inches of winter precipitation, but at the same time 12.7 inches were added by winter irrigation, making a total of winter water of 16.5 inches. In this case, it required 5.9 inches of summer irrigation to maintain the C plats against none for the preceding year and 8.8 inches to keep the B plat supplied with the required moisture against 2.6 for the succeeding year. This would appear to indicate that the winter irrigation had little effect on the summer requirements when compared with the winter precipitation. A much longer series of observations will be required, however, before trustworthy conclusions can be drawn in this connection.

In summing up the results of his experiments, Mr. Knapp presents the following conclusions:

The amount of water required to keep the soil moisture content at a given per cent of saturation varies somewhat with the kind of crops grown.

Crops differ greatly in the amounts of water which they can profitably use, and in the range of yield which can be effected by applying various amounts of water.

Milo shows a marked ability to increase in yield of grain as additional amounts of water are applied, and where the crop receives sufficient irrigation water it is affected less by unfavorable climatic conditions than the other crops included in this experiment. The yield of stover was not greatly influenced by increasing the amount of water.

Kafir exhibits much the same characteristics as milo, but is unable to respond to the application of water to the same extent as milo, so far as this is measured by the yield of grain.

Sumac sorgo was not able to use economically large amounts of water, and showed a slight falling off in yield of stover when more than about 15 inches was applied.

Sudan grass grown in rows for seed is not a profitable irrigation crop, and when it is so grown it should not be irrigated heavily.

The yields of small grain crops such as wheat, oats, and barley are controlled to a greater extent by prevailing weather conditions than by available amounts of water, and no amount of water has sufficed to insure good yields in years of adverse weather conditions.

THE WEATHER OF 1922.

By A. J. HENRY.

Cyclones and anticyclones.—The number of cyclones (189) and of anticyclones (129) which appeared within the field of observation during the year was considerably in excess of the 20-year average. That fact, however, does not necessarily indicate a year of greater storminess as some writers claim. The word "storminess" is, at best, a vague term when applied to average conditions unless the writer indicates clearly what is meant. The suffix "ness," added to the root "stormy," must mean, at least, greater violence of the winds, an increased amount of both cloudiness and precipitation. All of these characteristics are amenable to exact observation and tabulation and it is an easy matter to ascertain whether or not any given period has been one of strong winds, great precipitation, and naturally much cloudiness. The record of cyclones for the year very clearly shows that increased storminess can not be predicated upon a large number of cyclones. The important point to be remembered is that quality rather than quantity is the determining factor.

Precipitation.—Considering the United States as a single geographic unit its weather during 1922 may be briefly characterized as warm and moderately dry. More rain fell than in 1921, but the distribution throughout the year was very uneven. After a rainy spring and early summer, a shortage of rain was felt in more or less restricted areas in Atlantic Coast States, the Ohio Valley, and portions of the Plains States. The monthly distribution by climatological districts is shown in Table 1 and the departures from normal on chart A. J. H. II. This shortage continued, mostly in eastern districts, throughout November, and by that time the

shortage of water for manufacturing purposes and even for domestic use had become acute in portions of the Middle Atlantic States. Deficient rainfall was also the rule in Pacific Coast States, especially in Washington and Oregon.

The months of March, April, May, and June, the latter in eastern districts only, on the other hand, were months of abundant rains east of the Rocky Mountains; the rains of the two months first named laid the foundation for at least three great floods, as follows: (1) The Mississippi from the mouth of the Arkansas to the Passes, in which stretch of the river the greatest flood [1] of record culminated in June; (2) the rivers of Texas in April and May, including the flood of the lower Rio Grande in June; (3) the flood in the lower Colorado in California in May. Damaging floods, more or less local, occurred in the basins of the Delaware and Susquehanna in June and in the rivers of northwest Missouri in July due to repeated heavy downpours of rain.

[1] A detailed report of this flood will shortly appear in MONTHLY WEATHER REVIEW SUPPLEMENT No. 22 (The Spring Floods of 1922), by H. C. Frankenfield, Chief, River and Flood Division, Washington, 1923.

TABLE 1.—*Monthly and annual precipitation departures, 1922.*

Districts.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
New England	−1.4	−0.2	+0.7	−0.2	+0.8	+3.5	−0.2	+1.8	−1.1	−0.9	−2.4	−0.3	+0.1
Middle Atlantic	0.0	−0.4	+1.1	−1.1	−0.3	+2.2	+0.8	−0.3	−1.4	−0.8	−2.2	−0.0	−2.4
South Atlantic	−0.1	+1.5	+1.2	−0.2	+1.9	+0.4	−0.2	−0.9	−1.0	+1.8	−2.3	+0.6	+2.7
Florida Peninsula	−1.3	−0.9	−1.9	−1.6	+1.6	−3.3	+1.0	−0.3	+0.4	+5.2	+1.1	+0.6	+0.5
East Gulf	+0.6	+1.3	+2.6	−0.7	+2.9	−0.6	+0.4	−0.9	−2.4	+0.7	−1.4	+2.3	+5.0
West Gulf	+0.1	+0.1	+1.4	+2.5	+0.7	−0.1	−1.3	−1.7	−0.1	+0.1	−0.3	−1.5	−0.1
Ohio Valley and Tennessee	−1.4	−0.9	+2.6	+1.0	−0.3	−0.7	+0.1	−0.2	−0.4	−1.0	−1.7	+1.6	−1.3
Lower Lakes	−0.8	−0.5	+1.5	+0.4	−0.8	+1.6	−0.7	+0.4	−0.9	−0.9	−1.6	−0.3	−2.6
Upper Lakes	−0.8	+0.8	+0.4	+1.0	−0.9	−0.4	+0.6	−0.6	+0.5	−1.1	0.0	−0.8	−1.3
North Dakota	−0.2	+0.3	−0.2	−0.8	+0.5	−0.4	−0.8	−1.2	+0.5	−0.7	+1.3	+0.2	−1.5
Upper Mississippi Valley	−0.5	+0.5	+1.2	+0.6	−0.5	−2.3	+0.6	−1.2	−0.9	−0.9	+1.2	−0.6	−2.8
Missouri Valley	+0.1	+0 1	+1.5	+0.9	−1.2	−1.6	+0.8	−1.8	−0.7	−0.6	+2.0	−0.6	−1.1
Northern slope	−0.1	−0.1	−0.6	+0.7	−0.1	−1.1	+0.6	+0.1	−0.6	−0.4	+0.7	−0.1	−1.0
Middle slope	−0.1	+0.2	+1.0	+2.0	−0.2	−1.8	+0.6	−1.0	−0.8	0.0	+1.4	−0.6	+0.7
Southern slope	−0.2	−0.3	+0.7	+2.9	−0.4	+0.3	−1.6	−1.9	−1.9	−0.9	−0.2	−0.8	−4.3
Southern Plateau	0.0	−0.2	−0.1	0.0	−0.2	−0.2	−0.5	−0.4	−0.2	−0.5	+0.1	+0.4	−2.2
Middle Plateau	0.0	+0.7	−0.4	−0.2	−0.3	−0.1	+0.2	+0.6	−0.6	−0.5	+0.2	+0.6	+0.2
Northern Plateau	−0.6	−0.2	−0.4	−0.1	−0.9	−0.6	−0.4	+0.8	−0.5	−0.5	−0.8	+0.3	−3.9
North Pacific	−3.9	−2.0	+0.6	−0.5	−0.5	−1.7	−0.7	+0.8	+0.2	+0.1	−4.2	+0.7	−11.1
Middle Pacific	−2.3	+1.2	−1.4	−1.5	−0.7	−0.3	0.0	0.0	−0.5	+1.0	+0.2	+1.8	−2.5
South Pacific	+1.0	+1.1	−0.6	−0.8	0.0	0.0	0.0	0.0	−0.2	−0.5	+0.8	+1.2	+2.0

Temperature.—The tendency to above-normal temperature which has prevailed on this continent for some time continued through out the year, excepting only the area between the Rockies and the Pacific—an area that often differs in temperature distribution from the remainder of the country.

The dividing line between areas of positive and areas of negative temperature departure is shown on Chart A. J. H. I. The cold weather of January west of the Rockies brought freezing temperatures and considerable financial loss to citrus growers in southern California.

The tendency of the temperature distribution to continue in the same sense for several months is well illustrated by the departure charts published in this REVIEW for February, March, April, and May, 1922, in all of which subnormal departures are shown for the region west of the Rockies. In June temperature was everywhere above normal except a small area in western Texas. In July temperature was below normal over a large area east of the Rockies and above normal to the westward, a reversal of the prevailing conditions. This reversal soon came to an end in August, the subnormal area appeared on the Atlantic coast states in the east and in a part of the Pacific coast area only.

Table 2 shows the departures by month and for each of the 21 climatological districts into which the United States have been divided.

TABLE 2.—*Monthly and average monthly temperature departures, 1922.*

Districts.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Average monthly departure.
New England	−1.4	+1.7	+3.3	+1.8	+3.1	+1.6	−0.7	+0.1	+1.6	+0.8	+1.4	−2.0	+1.0
Middle Atlantic	−1.2	+3.7	+3.4	+2.2	+2.7	+1.6	−0.5	−1.5	+2.0	+2.4	+1.9	+1.1	+1.5
South Atlantic	−0.5	+5.1	+2.7	+2.8	+0.9	+1.4	+0.3	−2.2	+1.0	+1.6	+1.6	+4.8	+1.6
Florida Peninsula	+1.1	+2.6	+2.3	+3.0	−0.2	+0.1	−0.7	−0.7	−0.7	+1.2	+1.8	+4.0	+1.2
East Gulf	+1.6	+5.5	+0.7	+3.3	+0.5	+1.1	−0.4	−0.3	+2.6	+0.6	+3.2	+7.0	+2.1
West Gulf	−0.9	+4.1	−0.7	+1.9	+2.0	+0.8	+0.4	+2.0	+2.8	+1.3	+2.6	+5.9	+1.8
Ohio Valley and Tennessee	−0.3	+3.9	+3.3	+2.8	+2.7	+1.4	−0.8	−0.7	+3.5	+2.5	+2.7	+3.0	+2.0
Lower Lakes	−1.9	+3.6	+3.6	+1.9	+3.6	+0.8	−0.6	−0.3	+2.6	+0.8	+2.8	−0.2	+1.4
Upper Lakes	−0.2	+0.7	+4.1	+1.5	+6.0	+1.7	−1.2	+1.0	+3.4	+1.7	+4.8	−1.8	+1.8
North Dakota	+3.0	−6.0	+5.6	+2.6	+3.2	+1.8	−2.0	+4.8	+3.4	+3.3	+6.4	−2.9	+1.9
Upper Mississippi Valley	+0.6	+2.2	+4.1	+1.0	+3.7	+2.3	−1.9	+1.6	+3.3	+4.2	+5.5	+0.3	+2.2
Missouri Valley	+2.2	−0.1	+4.1	+2.0	+2.0	+3.1	−1.8	+3.5	+4.6	+4.0	+4.9	+0.4	+2.4
Northern slope	−3.1	−7.5	+0.3	−1.9	−0.2	+3.6	−0.9	+3.9	+4.1	+3.9	−1.3	−3.4	−0.2
Middle slope	+0.2	+2.3	+0.6	−0.8	+0.5	+2.6	−0.4	+4.1	+4.1	+2.7	+2.1	+3.0	+1.8
Southern slope	−1.2	+3.5	−0.1	0.0	+0.6	−0.7	+1.1	+4.0	+2.9	+1.0	+1.7	+4.2	+1.4
Southern Plateau	−3.0	−1.6	−3.1	−3.7	+0.5	+1.2	+1.2	+1.4	+3.5	+0.9	−2.9	+2.9	−0.2
Middle Plateau	−7.5	−3.8	−3.7	−5.4	0.0	+3.8	+1.5	+0.2	+4.2	+1.3	−3.3	+2.0	−0.9
Northern Plateau	−8.5	−3.3	−2.9	−4.2	−1.4	+4.8	+3.1	+1.9	+3.4	+4.0	−3.2	−4.2	−0.9
North Pacific	−3.1	−1.6	−2.5	−2.6	+0.2	+1.8	0.0	−0.3	+1.7	+1.8	−1.1	−2.4	−0.7
Middle Pacific	−3.7	−2.1	−2.2	−2.4	+0.8	+1.5	+1.7	0.0	+2.8	−0.6	−3.0	−0.6	−0.6
South Pacific	−2.1	−0.7	−1.7	−2.3	+0.8	+1.4	+0.9	+1.2	+4.3	+0.5	−2.0	+2.1	+0.2

A. J. H. I. Annual Temperature Departures (°F.) in the United States, 1922.

A. J. H. II. Annual Precipitation Departures (inches) in the United States, 1922.

Shaded portions show excess (+).
Unshaded portions show deficiency (—).

NOTES, ABSTRACTS, AND REVIEWS.

SIMULTANEOUS CLOUD PHOTOGRAPHS.

(Abstract.)

A circular letter from the National Meteorological Office of France announces an interesting plan for the photographing of the sky and clouds simultaneously from a large number of meteorological stations.

As set forth in this circular, the concept of a cloud system permits of placing in a single group the numerous states of the sky observed simultaneously over a wide extent. It thus furnishes a scientific basis for the classification and rational nomenclature of all the different forms of clouds. In this nomenclature the name of each kind of cloud will indicate the part it has in the vast scheme which constitutes the cloud system. In order, then, to establish such a classification effectively, it will be necessary to study the relation of all possible cloud forms in the various classes of the system.

The proposed program is divided into two parts. First, in the period beginning January 15 and ending January 21, 1923, it is proposed to photograph tbe sky simultaneously at all meteorological stations in France, including occupied Rhine territory, as nearly as possible at the time of the regular meteorological observations, namely, at 9 a. m. and 3 p. m. If this experiment proves successful it is hoped to extend the campaign by asking the cooperation of other countries and also the masters of trans-Atlantic liners. In this part of the program it suggested that the most opportune time would be about the occurrence of the 1923 autumnal equinox and that not less than three records should be obtained each day. The hours recommended are 7 a. m., 1 p. m., and 6 p. m. Of course it is recognized that on account of insufficient light for phtotographing it may be nececessary to delay the morning observation slightly or to advance the evening observation.

The data accompanying each negative should include the following: Date and hour of exposure; direction toward which the objective is pointed and its angular elevation; and finally the colors of the clouds. Furthermore, it is desirable that these notations accompanying the negatives should give accurate details concerning the clouds observed so that any defects in the developed photographs may be offset.—*H. L.*

THE INFLUENCE OF MOUNT ETNA ON FREE-AIR CURRENTS.

By FILIPPO EREDIA.

[Author's abstract from *Atti della Reale Accademia Nazionale dei Lincei*, Apr. 2, 1922, pp. 251-254.]

In a note presented to the Accademia Nazionale de Lincei there have been examined the results obtained from pilot-balloon soundings made at Catania, Sicily, between the months of April, 1912, and July, 1915.

Upon arranging these soundings by seasons, it appears that from 2,400 to 4,500 meters the northwest winds predominate. In the zone between 1,200 and 2,100 meters the prevailing wind varies according to the season, but with a prevalence of winds of the first quadrant,[1] particularly between 1,800 and 2,100 meters. Below 1,200 meters east winds predominate.

Classified according to the angle which the mean wind direction makes with the meridian, it is concluded that in winter the winds of the fourth quadrant are predominant, being from the west below 1,800 meters and from the northwest at higher elevations. In the spring, directions of the second quadrant prevail up to 900 meters; above this elevation to 1,500 meters winds of the third quadrant prevail, with winds of the fourth quadrant still higher.

In summer we find winds of the second quadrant up to 900 meters, winds of the first quadrant from that elevation to 1,200 meters, and northwest winds above 1,500 meters. In autumn up to 900 meters winds of the first quadrant predominate and above that elevation northwest winds prevail.

The conclusions of Prof. A. Ricco, based upon observations of the smoke of Mount Etna, concerning the movement of the upper currents, are thus confirmed.

Arranging the wind speeds for altitude intervals of 150 meters, it is evident that up to 1,800 meters the increase of speed with altitude is similar for all seasons; above this altitude the increase of speed is most rapid in summer and least rapid in winter. With the exception of spring, there is a diminution of speed at 3,600 meters, which is most strongly marked in summer.

Neglecting the elevations below 300 meters, in which the speeds are altered by the surface, the wind velocity can be represented by the formula:

$$\log V = a - b \log H$$

in which the constants a and b have the following seasonal values:

	Winter.	Spring.	Summer.	Autumn.
a	1.84	2.19	3.45	2.27
b	0.37	0.45	0.82	0.49

The wind speed is greater in summer than in winter and it seems that this phenomenon is related to the turning of wind with altitude. The lowest values of wind speed correspond to winter, when the winds are prevailingly northwest; in autumn the turning of wind is weak, and there is a sensible increase of speed; in spring and summer the turning of wind is most decided and there is a large increase of speed with increase of altitude.

The greater increase of summer compared with spring may be attributed to the great radiation of the massif of Mount Etna in that season which produces a more rapid diminution of air density with altitude, corresponding to the conclusions of Egnell, that the wind speed is inversely proportional to the density.[2]

ACCURACY OF PHOTOGRAPHIC DETERMINATIONS OF AURORAL LIGHTS.[3]

This monograph deals with the accuracy of photographic determination of auroral lights with base lines several tens of kilometers in length. The maximum departures of individual determinations from the averages from three base lines are from 1.5 to 2.3 per cent. The differences between the averages determined by two independent methods for reducing the observations amount to but 5 per cent. The plates show different types of auroras photographed in southern Norway.—*C. F. B.*

[1] Evidently the author regards as belonging to the first quadrant those winds blowing from azimuths 0° to 90°,—0° being north and azimuth being measured clockwise.

[2] It is suggested that the heating of the Sahara in summer would induce stronger free-air pressure gradients than obtain in winter, and this would account also for the increase recorded.

[3] *Notes relative aux aurores boreales*, by Carl Störmer, Geof. Pub., Vol. II, No. 8, Kristiania, 1922. 15 pp., 8 pl.

SOLAR PROMINENCE ACTIVITY.

[Reprinted from *Nature*, London, Jan. 6, 1923, p. 27.]

Every half year the Kodaikanal Observatory, India, issues a bulletin giving a summary of prominence observations during that period. The data for the first half of the present year [1922], in Bulletin No. LXX, have just been received. The mean daily areas and daily numbers of the prominences are few, as was to be expected from the cyclical nature of the phenomena, the respective figures being 3.17 (square minutes) and 11.05. Their distribution in latitude shows maxima in the belt 45°–50° in both hemispheres, and is very similar to that for the previous half year; this indicates that a new cycle of activity has begun in the higher zones of prominences. The statistics give further the distribution of prominences east and west of the sun's axis, the activity of the metallic prominences, particulars of the displacements of lines observed in the spectra of the chromosphere and prominences, reversals and displacements of H_a and D_3, and finally, areas and numbers of prominences projected on the disc as absorption markings. These valuable data are of great importance because they provide a complete record of the activity of the sun from a prominence point of view on a homogeneous system.

BACK NUMBERS OF THE REVIEW WANTED.

In order to complete file sets and volumes for binding, the following issues of the MONTHLY WEATHER REVIEW and SUPPLEMENTS are earnestly desired. If any recipients of the REVIEW do not care to retain their copies, they will confer a favor by notifying the Chief of Bureau, Weather Bureau, Washington, D. C., who will be glad to forward necessary franks for the mailing of the issues listed below:

1914.

February, March, April, October, and December.

1915.

All months *excepting* January, October, and November.

1916.

January, February, June, August, September, and October.

1918.

February, August.

1919.

August.

1921.

March, June, July, August, October, and November.

1922.

March, April.
SUPPLEMENT Nos. 1, 2, and 3.

BIBLIOGRAPHY.

RECENT ADDITIONS TO THE WEATHER BUREAU LIBRARY.

C. FITZHUGH TALMAN, Meteorologist in Charge of Library.

The following have been selected from among the titles of books recently received as representing those most likely to be useful to Weather Bureau officials in their meteorological work and studies:

Béron, Pierre.
Météorologie simplifiée par l'application de la loi physique au mode de la production: 1° de la chaleur terrestre par celle du soleil; 2° des courants maritimes; 3° des saisons avec les climats; 4° des vents avec les pluies; et 5° de l'électricité avec l'état magnétique; ouvrage indispensable aux marins. Paris. 1863. p. 723–944. illys. 22½ cm. [Extr.: L'Electrologie, nov.–déc.]

Beveridge, William H.
Wheat prices and rainfall in western Europe. [London.] 1922. p. 412–478. plates (fold.) 21½ cm. (Repr.: Journal Royal statistical society. v. 85, pt. 3. May, 1922.)

Bianconi, Gian Antonio.
Sul clima d'Europa all'epoca glaciale. Bologna. 1872. 28. p. 29½ cm.

Bigelow, Frank Hagar.
Treatise on the sun's radiation. Supplement no. 4. Atmospheric radiation, electricity, and magnetism. Vienna. 1922. viii, 89 p. illus. 23 cm.

Braak, C.
On cloud-formation. Nuclei of condensation, haziness, dimensions of cloud-particles. Batavia. 1922. 33 p. 27 cm. (K. Mag. en met. observ. Batavia. Verh. No. 10.)

Castrillón, Álvarez.
Recurrència mitjana de l'estat higromètric a l'observatori Fabra. Barcelona. 1922. 8 p. illus. plate. 22 cm. (Servei meteorològic de Catalunya. Notes d'estudi. N.° 10.)

Colombia. Observatorio meteorologico nacional del colegio de San Bartolome.
Discursos leidos en su inauguracion el dia 24 de Septiembre de 1922. Bogotá. 1922. 18 p. plates. 24 cm.

Defant, Albert.
Ausstrahlung, nächtliche Abhühlung und Bewölkung. p. 99–108. 25 cm. (Extr.: Geografiska annaler. H. 1. 1922.)
Die Bestimmung der Turbulenzgrössen der atmosphärischen Zirkulation aussertropischer Breiten. Wien. 1921. p. 383–403. figs. 24½ cm. Extra.: Sitzungsber. Akad. der Wissensch. Mathem.–naturw. Klasse. Abt. IIa. Bd. 130, H. 7–8, 1921.)
Die Zirkulation der Atmosphäre in den gemässigten Breiten der Erde. p. 209–266. figs. 25 cm. (Extr.: Geografiska annaler. H. 3. 1921.)

Dujardin.
La chaleur et l'humidité à la surface de la terre. Paris. 1867. 96 p. illus. 15 cm.

Eichhorn, A.
Die klimatischen Verhältnisse von Lüneburg. Nach den Beobachtungen der hiesigen meteorologischen Station. Lüneburg. 1922. 39 p. illus. 22½ cm.

Errulat, F.
Die Fernwirkungen der Explosion von Rothenstein bei Königsberg i Pr. am 10. April 1920 mit besonderer Berücksichtigung der Bodenerschütterungen. 59 p. illus. plates. 25½ cm. (Mitt. Geol.-paläontol. Inst. und der Bernsteinsamml. der Univ. Königsberg i Pr. N. F. Nr. 25.) (Schriften d. Physik.-ökonom. Gesellschaft. Jahrg. 63, 1922.)

Febrer, Joaquim.
Pluges a Catalunya durant l'any meteorològic de 1920–1921. Barcelona. 1922. 8 p. illus. 22 cm. (Servei meteorològic de Catalunya. Notes d'estudi. N°. 9.)
Pluges a Catalunya durant la primavera de 1922. Barcelona. 1922. 8 p. illus. 23 cm. (Servei meteorològic de Catalunya. Notes d'estudi. N°. 11.)

Fischer, Hanns.
Die Wunder des Welteises. Eine gemeinverständliche Einführung in die Welteislehre Hanns Hörbigers. Berlin-Wilmersdorf. 1922. 104 p. illus. 19½ cm.

Frantzen, L. P.
Utilisations scientifiques et militaires des planeurs captifs cerfs-volants. pt. 1-2. 26, 14 p. illus. 24 cm. (Bulletin mensuel de l'assoc. des anciens élèves de l'école centrale lyonnaise. 19e année. Août-sept. 1922.)

Graeger, N.
Sonnenschein und Regen und ihre Einflüsse auf die ganze Schöpfung. Eine populäre Witterungskunde für Nichtmeteorolgen. Weimar. 1870. x, 242 p. figs. map. 21 cm.

Hansen, H.
Meteorological observations on the Alabama expedition. København. 1922. p. 217-295. figs. 27½ cm. (Alabama-Ekspeditionen til Nordøst-Grønland, 1909-1912.) (Meddelelser om Grønland. 52.)

Hayford, John F.
Effects of winds and of barometric pressures on the Great Lakes. Washington. 1922. v, 133 p. plates. 25½ cm. (Carnegie inst. of Washington. Publication no. 317.)

Hernandez, Maurici.
Les temperatures màximes i mínimes a Mahó. Barcelona. 1922. 8 p. 22 cm. (Servei meteorològic de Catalunya. Notes d'estudi. N°. 13.)

Ihne, E.
Phaenologische Mitteilungen, Jahrgang 1921. Darmstadt. 1922. 34 p. 23½ cm. (Arbeiten der Landwirtschaftskammer für Hessen. H. Nr. 31.)

International library of technology.
. . . Nautical astronomy, latitude, longitude and azimuth, Sumner's method, Marcq St. Hilaire's method, ocean meteorology, international rules and signals. Scranton. 1922. v. p. illus. 23 cm.

Italy. Servizio idrografico.
Determinazione preliminare della superficie dei bacini imbriferi con elenco delle stazioni idrografiche in funzione al 31 Dicembre 1919. [Roma.] n. d. 23 p. 23x34 cm.

Jensen, Christian.
Die Atmosphäre der Erde . . . Wolken und Wetter. Hamburg. 1922. 24 p. illus. plates. 14 cm.

Jones, Wellington D., & Whittlesey, D. S.
Types of climate . . . Chicago. 1922. 17 p. map. 23 cm. (Reprint Principles of economic geography.)

Maffei, Ranieri.
Dell' influenza dell' aria su i temperamenti, malattie, ed inclinazioni degli uomini. Livorno. 1765. 126 p. 21 cm.

Malde, O. G.
Local forecasting of his own cranberry bog very important for the Wisconsin cranberry grower. p. 25-29. 23 cm. (Extr. Wisconsin state cranberry growers' assoc. 35th annual meeting, Jan. 10, 1922.)

Mann, Robert James *& others*.
Die moderne Meteorologie. Sechs Vorlesungen, gehalten auf Veranlassung der meteorologischen Gesellschaft zu London. Deutsche orig.-Ausgabe. Braunschweig. 1882. x, 217 p. plates. 21½ cm.

Marvin, Charles F.
Reform of the calendar. [Washington. 1922.] 3 p. 24½ cm. [Repr.: Weather bureau topics and personnel.]
United States weather bureau: report prepared for the commission of the United States of America to the Brazil centennial exposition 1922-1923. Washington. 1922. 8 p. 23½ cm. [Editions also in Spanish and Portuguese.]

Moidrey, Joseph de.
Manuel élémentaire de météorologie. Zi-ka-wei. 1914. unp. 23 cm. [Text in Chinese.]

Montagne.
La houle sur les côtes du Maroc. Observations et méthode de prediction. pt. 1-2. n. p. [1922.] tables. plates. 31 cm. [Manifolded.]

Moore, Willis Luther.
New air world; the science of meteorology simplified. Boston. 1922. xii, 326 p. illus. plates. charts. 21 cm.

Moreau de Jonnès, A.
Tableau du climat des Antilles, et des phénomènes de son influence sur les plantes, les animaux et l'espèce humaine. Paris. 1817. 84 p. 21 cm.

Newbigin, Marion I.
Frequented ways: a general survey of the land forms, climates, and vegetation of western Europe, considered in their relation to the life of man; including a detailed study of some typical regions. London. 1922. xi, 231 p. illus. plates. 23 cm.

Novakovsky, Stanislaus.
Climatic provinces of the Russian Far East in relation to human activities. New York. [1922.] p. 100-115. illus. 25½ cm. (Repr.: Geographical review. v. 12, Jan., 1922.)
Effect of climate on the efficiency of the people of the Russian Far East. p. 275-283. 27 cm. (Extr.: Ecology. v. 3, Oct., 1922.)

Quixal, Antoni.
Sondatges de l'atmòsfera lliure a Barcelona amb globus pilots, des del 19 de Setembre de 1921 al 30 de Setembre de 1922. Barcelona. 1922. 24 p. 22 cm. (Servei meteorològic de Catalunya. Notes d'estudi. N.° 12.)

U. S. Bureau of efficiency.
Report on the statistical work of the United States government submitted to congress in pursuance to the acts of March 1, 1919, and November 4, 1919. Washington. 1922. xv, 405 p. plates (fold.) 23½ cm. [Weather bureau, p. 174-181.]

Visser, S. W.
Inland and submarine epicentra of Sumatra and Java earthquakes. Batavia. 1922. 14 p. plates. 27½ cm. (K. Mag. en met. obs. te Batavia. Verhandl. no. 9.)

Zealley, P. Raymond.
Introduction to forecasting weather. Cambridge. 1922. 32 p. illus. front. 19 cm.

RECENT PAPERS BEARING ON METEOROLOGY AND SEISMOLOGY.

C. F. TALMAN, Meteorologist in Charge of Library.

The following titles have been selected from the contents of the periodicals and serials recently received in the Library of the Weather Bureau. The titles selected are of papers and other communications bearing on meteorology and cognate branches of science. This is not a complete index of all the journals from which it has been compiled. It shows only the articles that appear to the compiler likely to be of particular interest in connection with the work of the Weather Bureau.

American meteorological society. Bulletin. Worcester, Mass. v. 3. 1922.
Visher, Stephen Sargent. Local climates in the tropics. p. 119-121. (Sept.)
Alter, J. Cecil. Weather exhibit. p. 158-159. (Nov.)
Brooks, Charles F. The coming winter in the northeastern United States. p. 151-152. (Nov.)
Brooks, Charles F. Wet bulb temperatures below 32° F. p. 159-160 (Nov.)
Campbell, E. S. A preliminary plan for teaching pupils of junior high school age some facts about the atmosphere and weather. p. 153-156. (Nov.)
Garrett, C. C. Temperature and the codling moth. p. 153. (Nov.)

Annalen der Hydrographie und maritimen Meteorologie. Berlin. 50. Jahrg. 1922.
Kuhlbrodt, Erich. Das Windsystem im Fuss der Sachsenwaldtrombe von 28. Juni 1920. p. 154-158. (Mai.)
Thorade, H. Die ablenkende Kraft der Erdumdrehung. p. 150-154. (Mai.)
Bongards, Hermann. Der tägliche Gang des Luftdrucks. p. 169-182. (Juni.)
Casten, Gerhard. Neuere englische Bezeichnungen für Windarten. p. 206-209. (Juli.)
Wegener, Kurt. Die Entstehung des Nebels. p. 209-211. (Juli.)
Benkendorff. Neuerungen im deutschen drahtlosen Wetternachrichtendienst. p. 235-237. (Aug.)
Brennecke, W. E. von Drygalskis Werk über das Eis der Antarktis und der subantarktischen Meere. p. 222-229. (Aug.)
Petersen. P. Die Eisverhältnisse an den deutschen Küsten während des Winters 1921/22. p. 244-251. (Sept.)
Seilkopf, Heinrich. Eisnachrichtendienst. p. 252-255. (Sept.)
Wegener, Alfred, & Kuhlbrodt, Erich. Der Spiegeltheodolit für Pilot- und freie Registrierballonaufstiege auf See. p. 241-244. (Sept.)

Aviation. New York. v. 14. Jan. 8, 1923.
The Weather Bureau and aviation. Annual report details forecast work in aid of aviation and aerological investigations. p. 46-47.

Ciel et terre. Brux. 38 année. Nov.-Déc. 1922.
Gorcznski, Ladislas. Sur la situation climatique de la Pologne et sur son degré de continentalisme. p. 375-388.
Jaumotte, J. Sur le déplacement du zéro dans l'électromètre de Mascart. p. 363-368.
L., E. Le tremblement de terre de Coquimbo (La Serena) et du Chili. p. 390-393.
Lagrange, E. Ole Roemer et le thermomètre Fahrenheit. p. 357-363.
Navarro, Manuel Maria S. Le barographe à mercure "Loyola." p. 371-375.

Engineering news-record. New York. v. 90. Jan. 18, 1923.

Chisholm, Edward N. Hydrologic record of the Mississippi floods from 1882 to 1922. Official statement of gage heights from Cairo to the Gulf in all the high waters of the past 40 years—Record of the present status of levee construction. p. 112–116.

Great Britain. Meteorological office. British rainfall, 1921. London.

Brownlee, John. Rainfall and scarlet fever. p. 386–387.

The drought of 1921. p. 270–285.

Glasspoole, John. The fluctuations of annual rainfall. p. 288–300.

Meteorologia pratica. Montecassino. Anno 3. Sett.-Dic. 1922.

Leonardi, Evelino. Il freddo, il caldo e la salute dell'uomo. p. 147–150.

La morte del nostro collaboratore Antonio Favaro. p. 199. [Obituary.]

L'osservatorio della R. Università di Parma. p. 182–183.

Fantoli, Amilcare. L'osservatorio di Tripoli e la rete meteorologica della Libia. p. 186–187.

Paoloni, D. B. Sui limiti del giorno piovoso. p. 170–173.

La specola meteorico-sismica "Vincenzo Nigri" di Foggia. p. 183.

Meteorological magazine. London. v. 57. 1922.

The experimental study of the propagation of sound. The explosion of October 28th, 1922. p. 278–279. (Nov.)

Entwistle, F. The Royal aero club gliding competition, October 16th to October 21st, 1922. The meteorological conditions. p. 263–266. (Nov.)

Shaw, Napier. Change of wind on the turn of the tide. p. 269–270. (Nov.)

Stefan C. Hepites. p. 282. (Nov.) [Obituary.]

Botley, Cicely M. Meteorology and folklore. The wind. p. 307–308. (Dec.)

Brooks, Charles F. Cloud transformations. p. 303–304. (Dec.)

Cargil Gilston Knott. p. 314. (Dec.) [Obituary.]

Dines, L. H. G. Evaporation from a tank at Valencia observatory. p. 310–311. (Dec.)

The effect of introducing ammonia into pilot balloons. p. 309–310. (Dec.)

Mill, Hugh Robert. The evolution of climate: A review. p. 295–297. (Dec.)

Mulholland, P. I. Exceptional visibility as a sign of coming rain. p. 304. (Dec.)

Shaw, Napier. The dynamics of the circular vortex. Note on the recent work of Prof. V. Bjerknes. p. 298–299. (Dec.)

Twist, T. F. A persistent rainbow: Porlock, September 16th, 1922. p. 306. (Dec.)

Meteorologische Zeitschrift. Braunschweig. Bd. 39. Nov., 1922.

Ångström, Anders. Einige Bemerkungen zu meinen Studien zum Frostproblem, mit besonderer Berücksichtigung eines Referats von W. Schmidt. p. 361–363.

Dorno, C. Über spezifisch-medizinische Klimatologie. p. 344–348.

Dorno, C. Zum Vergleich des ersten Beobachtungsjahres der Steiermärkischen Sonnenheilstätte Stolzalpe und Davos. p. 355–356.

Ficker, H. Ein bemerkenswertes Barogramm bei einen Hagelsturm in Wien. Nov. 1922. p. 353–355.

Fischer, Karl. Die Seeverdunstungsmessungen der preussischen Landesanstalt für Gewässerkunde. p. 337–342.

Köppen, W. Monatliche Regenmengen von 90 Orten NW-Europas. p. 357–360.

Köppen, W. Warum ist das Mittel aus den täglichen Extremen höher als das 24-stundige Temperaturmittel? p. 363.

Marten, W. Zur Frage der absoluten pyrheliometrischen Skala. p. 342–344.

Rubinstein, E. Die Differenz der mittleren Monatstemperaturen zweier benachbarter Stationen als eine meteorologische Konstante. p. 348–353.

Wilfer & Schmidt, Wilhelm. Hohe Blitzgefahr auf schmalen Streifen. p. 360–361.

National geographic magazine. Washington, D. C. v. 43. January, 1923.

Bentley, Wilson A. The magic beauty of snow and dew. p. 103–112.

Nature. London. v. 110. 1922.

The Chilian earthquake. p. 683–684. (Nov. 18.)

Fisher, Willard J. Waterspouts. p. 669. (Nov. 18.)

Watt, R. A. Watson. The origin of atmospherics. p. 680–681. (Nov. 18.)

Rayleigh. Spectrum of the night sky. p. 769. (Dec. 9.)

Shaw, Napier. Meteorological theory in practice. p. 762–765. (Dec. 9.) [Review of L. F. Richardson's "Weather prediction by numerical process."]

Solar radiation at Helwan observatory. p. 790–791. (Dec. 9.)

Dines, W. H. The cause of anticyclones. p. 845. (Dec. 23.)

Nature. Paris. 50 année. 1922.

Nodon, Albert. Les courants telluriques. p. 339–342. (25 nov.) p. 355–359. (2 déc.)

Les radiotélégrammes sismologiques de Strasbourg. p. 173–174. (2 déc.)

Barbier, Jean-Emile. À propos du récent séisme du Chili. p. p. 398–400. (16 déc.)

Bidault de l'Isle, G. Un curieux aspect du ciel au coucher du soleil. p. 415–416. (23 déc.)

Une semaine des nuages. Suppl. p. 197. (23 déc.) [Campaign of cloud photography in France during January, 1923. Cf. this REVIEW, p. 649.]

Philosophical magazine. London. v. 44. November, 1922.

Bond, W. N. A wide angle lens for cloud recording. p. 999–1002.

Milne, E. A. Radiative equilibrium: the insolation of an atmosphere. p. 872–896.

Photodramatist. Los Angeles, Calif. Dec., 1922.

Johnson, Eynonah. "Weather effects" in the films. p. 21–23.

Popular astronomy. Northfield, Minn. v. 30. November, 1922.

Rordame, Alfred. The atmosphere of Venus. p. 517–523.

Weil, Mabel. Theories on the nature of meteor trains, with a note on Professor Trowbridge's contributions to our knowledge of meteor trains. p. 524–535.

Popular science monthly. New York. v. 101. December, 1922.

Mount, Harry A. Why our homes breed winter sickness. p. 32–34; 110–111.

Royal society of London. Proceedings. London. Ser. A. v. 102. January, 1923.

Lindemann, F. A., and Dobson, C. M. B. A theory of meteors, and the density and temperature of the outer atmosphere to which it leads. p. 411–437.

Watt, R. A. Watson. Directional observations of atmospheric disturbances. p. 460–478.

Science. New York. v. 56. November 24, 1922.

Bauer, Louis A. Earth-current observations. p. 592–594.

Scientific American. New York. v. 127. December, 1922.

Bull, Anders. Fog signaling by polarized sound. p. 406–407.

Seismological society of America. Bulletin. Stanford university. v. 12. June–September, 1922.

Cotton, Leo A. Earthquake frequency, with special reference to tidal stresses in the lithosphere. p. 49–198.

Sociedad geográfica de Lima. Boletín. Lima. t. 36. Trimestre 2–3, 1920.

Remy, Fed. E. Climatología de Lima en el año 1919. Observatorio "Unanue." p. 147–155.

Società meteorologica italiana. Bollettino bimensuale. Torino. v. 41. Settembre–Dicembre 1922.

Sulla variazione annua del barometro a Milano. p. 53–64.

Tenani, Mario. Sul calcolo dell' energia del vento. p. 65–68.

Tycos-Rochester. Rochester, N. Y. v. 13. January, 1923.

Pearsons, S. K., jr. Long-range weather forecasts impossible. p. 18–19.

Umschau. Frankfurt. 26. Jahrg. 28. Okt. 1922.

Becker, Hans Karl. Eine deutsche Eishöhle. p. 676–678.

Wetter. Berlin. 39. Jahrg. Novbr./Dezbr. 1922.

Bongards, H. Das Flugzeug im Dienste wetterkundlicher Forschung. p. 182–187.

Hellman, G. Deutschlands Klima. p. 161–174.

SOLAR OBSERVATIONS.

SOLAR AND SKY RADIATION MEASUREMENTS DURING DECEMBER, 1922.

By HERBERT H. KIMBALL, In Charge, Solar Radiation Investigations.

For a description of instruments and exposures and an account of the method of obtaining and reducing the measurements, the reader is referred to this REVIEW for April, 1920, **48**: 225.

From Table 1 it is seen that direct solar radiation intensities averaged very close to normal values for December at all three stations.

Table 2 shows that the total solar and sky radiation received on a horizontal surface averaged below the December normal at Washington and Madison, and considerably above the normal at Lincoln. For the year the record for Washington shows a deficiency of 3.5 per cent of the annual mean, and the record for Madison a deficiency of 1.7 per cent.

Skylight polarization measurements made on six days at Washington give a mean of 58 per cent, with a maximum of 64 per cent on the 19th. These are average polarization values for December at Washington. At Madison no measurements were obtained during the month, as the ground was covered with snow after the 13th.

TABLE 1.—*Solar radiation intensities during December, 1922.*

[Gram-calories per minute per square centimeter of normal surface.]

Washington, D. C.

Date.	Sun's zenith distance.										
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon.
	75th meridian time.	Air mass.									Local mean solar time.
		A. m.					P. M.				
	e.	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0	e
	mm.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	mm.
Dec. 2	3.15				1.30						2.74
5	7.57				1.12			0.98	0.86		4.75
6	2.06	0.78	0.90	1.03	1.09			0.86	0.66	0.56	2.36
18	3.15				1.02						2.49
19	1.45				1.24	1.47		1.06	0.87	0.75	1.52
20	1.78		0.71	0.89							2.62
21	3.99				1.12			0.86	0.73	0.61	3.45
29	3.00	0.79	0.96	1.19	1.43	1.61		1.21	1.11	1.00	3.15
30	2.26	0.93	1.02	1.12							2.16
Means		0.83	0.90	1.06	1.19			0.99	0.85	0.73	
Departures		+0.05	+0.01	+0.02	−0.03			−0.02	−0.03	−0.03	

TABLE 1—*Solar radiation intensities during December, 1922*—Con.

Madison, Wis.

Date.	Sun's zenith distance.										
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon.
	75th meridian time.	Air mass.									Local mean solar time.
		A. M.					P. M.				
	e.	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0	e.
	mm.	cal	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	mm.
Dec. 2	2.36			1.12							3.45
5	1.32	1.06	1.16	1.28		1.50					1.60
13	0.81		1.00								1.12
18	0.46	1.12	1.18								0.58
Means		(1.09)	1.11	(1.20)							
Departures		+0.13	−0.02	−0.02							

Lincoln, Nebr.

Date.	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon.
Dec. 5	1.45	0.84	0.96	1.23		1.65		1.01			1.32
12	0.74	1.16	1.18	1.35		1.56					0.56
15	1.07			1.20		1.49		1.22	1.05	0.89	1.60
20	1.68			1.23				1.18			1.68
22	3.30		1.00								3.30
Means		(1.00)	1.05	1.25				1.14	(1.05)	(0.89)	
Departures		+0.08	±0.00	+0.02				−0.05	−0.01	−0.06	

* Extrapolated.

TABLE 2.—*Solar and sky radiation received on a horizontal surface.*

Week beginning.	Average daily radiation.			Average daily departure for the week.			Excess or deficiency since first of year.		
	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.
	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.
Dec. 3	123	121	160	−34	−2	−18	−3,864	−1,826	
10	85	134	191	−66	+9	+15	−4,327	−1,760	
17	148	125	210	−3	−1	+35	−4,347	−1,770	
24	142	92	209	−10	−40	+31	−4,430	−2,090	

WEATHER OF NORTH AMERICA AND ADJACENT OCEANS.

NORTH ATLANTIC OCEAN.

By F. A. YOUNG.

The average pressure for the month was somewhat above the normal at land stations on the Atlantic coasts of Canada and the United States, north of New York, as well as in the Bermudas and Azores. The pressure was near the normal in the Gulf of Mexico and West Indies, while it was much lower than usual on the coast of Northern Europe, although in that region there was a large difference between the means for the first and last halves of the month. At Lerwick, Shetland Islands, the mean for the first 16 days was about 29.9 inches, and for the last 15, 29.1 inches, while the normal is approximately 29.8 inches. The pressure at Horta, Azores, remained comparatively constant during the month, the mean for the first half being about 0.1 inch lower than that for the second half.

Fog was apparently rare over the steamer lanes, east of the 40th meridian, while the number of days in which it occurred on the Banks of Newfoundland and off the American coast was not far from the normal. It was reported, however, on four days in the Gulf of Mexico, which occurrence was most unusual.

The consensus of opinion in maritime circles seems to be that the weather over the North Atlantic during the month under discussion, was the most severe known in years, and according to press reports a number of the masters of trans-Atlantic liners stated that they had not experienced such a succession of days with heavy winds and tempestuous seas in 30 years or more. An examination of a large number of vessel reports confirms this contention, and the month was remarkable not alone for the severity of many of the gales, but also for the large number of disturbances of cyclonic origin that swept over the steamer lanes in quick succession. Several vessels in their voyage across the Atlantic encountered from four to five separate gales, with very short intervals of moderate weather in between. While a large number of casualties was reported, it seems remarkable that the loss of life and property was not greater.

The month opened auspiciously. While a few reports were received indicating gales over the western part of the steamer lanes from the 1st to the 4th, it was not until the 5th that the heavy weather really began. On that date there was a well-developed disturbance central about 5° east of St. Johns, Newfoundland, and there was also a second area of low pressure of moderate intensity off the coast of New Jersey. The first disturbance moved rapidly in a north-northeasterly direction and on the 6th was central near latitude 52° N. longitude 37° W. The second drifted eastward, increasing rapidly in intensity, and on the 6th the center was near latitude 42° N, longitude 57° W. Moderate to strong gales prevailed over the greater part of the ocean west of the 30th meridian the storm area extending as far south as the 35th parallel. By the 7th the first disturbance had apparently moved north so rapidly that it was outside the track of vessels, while the second was now near the position occupied by the first on the 6th. The storm area had contracted slightly, although the region between the 30th and 60th meridians was still swept by gales. On the 6th northerly to easterly winds of force 7 were reported from the region between the 10th and 20th parallels and 70th and 80th meridians. From the 8th to the 11th gales were reported from widely scattered portions of the ocean.

Storm logs covering the period from the 4th to the 12th follow.

British S. S. *Indian:*

Gale began on the 5th, wind WNW. Lowest barometer 30.12 inches at 6 p. m. on the 6th, wind W. 9, in latitude 37° 32′ N., longitude 67° 45′ W. End on the 7th, wind NNW. Highest force of wind 9; shifts NW.-WNW.-NW.

American S. S. *Schroon:*

Gale began on the 4th, wind ESE. Lowest barometer 28.40 inches at 7 p. m. on the 6th, wind S., 10, in latitude 44° 25′ N., longitude 49° W. End on the 8th, wind WNW. Highest force of wind 11; shifts S.-SW.

American S. S. *Schodack:*

Gale began on the 4th, wind E, 8. Lowest barometer 29.16 inches at 3 a. m. on the 6th, wind W., 11, in latitude 42° N., longitude 61° W. End on the 7th, wind WNW. Highest force of wind 12; shifts SSE.-SW.-WNW.

American S. S. *Mexican:*

Gale began on the 6th, wind WNW. Lowest barometer 28.85 inches at midnight on the 6th, wind S., in latitude 45° 25′ N., longitude 46° W. End on the 7th, wind W. Highest force of wind 12, S.; shifts W.-S.

British S. S. *Winterton:*

Gale began on the 4th, wind E. Lowest barometer 28.83 inches at 10 p. m. on the 6th, wind S., 12, in latitude 46° 30′ N., longitude 42° W. End on the 7th, wind NNW. Highest force of wind 12, S.; shifts S.-W. back to SW.

Italian S. S. *Maria:*

Gale began on the 6th, wind WSW. Lowest barometer 29.84 inches at 3 a. m. on the 7th, wind WSW., 8, in latitude 34° 23′ N., longitude 47° 48′ W. End on the 9th, wind WSW. Highest force of wind 11, W.; shifts WSW.-W.-WNW.-W.-WSW.

American S. S. *Tripp:*

Gale began on the 7th, wind SSE. 7. Lowest barometer 29.25 inches at 8 a. m. on the 8th, wind SSW., 9, in latitude 43° 13′ N., longitude 33° 30′ W. End on the 9th. Highest force of wind 10, SW.; shifts SSE.-S.-SSW.

British S. S. *Alpine Range:*

Gale began on the 8th, wind SW. Lowest barometer 29.40 inches at midnight on the 8th, wind SE., 10, in latitude 53° 20′ N., longitude 32° 54′ W. End on the 9th, wind W. Highest force of wind 11; shifts SE.-S.-SW.-W.

From the 10th to the 13th a series of NW. and N. gales blowing with hurricane force at times, each gale lasting about 3 hours. Average low barometer reading 29.66 inches. Position, from latitude 52° 12′ N., longitude 36° 52′ W., to 47° 56′ N., 37° 10′ W. Shifts of wind NW.-N. and back to NW.

American S. S. *Rochester:*

Gale began on the 10th. Lowest barometer 30.14 inches at 10 a. m. on the 10th, wind ENE., 8, in latitude 31° N., longitude 78° 05′ W. End on the 11th. Highest force of wind 9; shifts NE.-ENE. and back to NE.

Belgian S. S. *Keltier:*

Gale began on the 11th, wind S. Lowest barometer 29.95 inches at 2 p. m. on the 12th, wind SSW., 11, in latitude 38° 27′ N., longitude 70° 05′ W. End on the 12th, wind W. Highest force of wind 11; shifts 6 points.

On the 13th there was an area of low pressure in the vicinity of Newfoundland, while the Icelandic LOW was also well developed. Gales prevailed over different sections of the steamer lanes interspersed with areas of moderate winds. On the 14th and 15th the storm area was restricted to a comparative limited region in mid-ocean, while on the 15th a second disturbance was central near latitude 40° N., longitude 55° W.

At the Greenwich mean noon observations on the 16th moderate weather was the rule over practically the entire ocean, although a disturbance appeared later in the day over the eastern section, where unusually low pressure with cyclonic disturbances in quick succession, prevailed until the end of the month. However, the extent and intensity of the storm areas varied somewhat from day to day.

Storm logs from vessels in the eastern sections of the ocean during the period from the 13th to 31st are as follows:

British S. S. *Lord Antrim:*

Gale began on the 16th, wind SW. Lowest barometer 29.01 inches at 10 a. m. on the 17th, wind WSW., in latitude 51° 05′ N., longitude 19° 15′ W. End on the 18th, wind W. Highest force of wind 11; shifts SW.-WSW.-W.

Danish S. S. *United States:*

Gale began on the 17th, wind ENE. Lowest barometer 28.62 inches at 8 a. m. on the 17th, wind ENE., in latitude 55° 20′ N., longitude 24° 12′ W. End on the 17th. Highest force of wind 10; steady from ENE.

French S. S. *La Savoi:*

Gale began on the 17th, wind SW., 7. Lowest barometer 28.75 inches at 4 p. m. on the 20th, wind SW., 12, in latitude 49° 06′ N., longitude 28° 11′ W. End on the 23d. Highest force of wind 12, SW.; shifts SSW.-WNW.

British S. S. *Chickahominy:*

Gale began on the 17th, wind W. Lowest barometer 28.95 inches at 8 a. m. on the 18th, wind W., 10, in latitude 51° 08′ N., longitude 19° W. End on the 19th, wind W. Highest force of wind 11; steady from W.

Danish M. S. *Peru:*

Gale began on the 21st, wind SW. Lowest barometer 29.00 inches at 8 a. m. on the 23d, wind W., 11, in latitude 42° 13′ N., longitude 21° 40′ W. End on the 23d, wind N. Highest force of wind 11, NNW.

American S. S. *Westland:*

Gale began on the 22d, wind W. Lowest barometer 29.61 inches at noon on the 22d, wind WNW., in latitude 44° 30′ N., longitude 16° 10′ W. End on the 24th, wind N. Highest force of wind 11, W.; shifts W.-WNW.-NW.

French S. S. *Canada:*

Gale began on the 23d, wind WSW. Lowest barometer 29.70 inches at 3 a. m. on the 24th, wind W., 10, in latitude 36° 35′ N., longitude 11° 30′ W. End on the 25th, wind NE. Highest force of wind 10; shifts WSW.-W.-NW.

Danish S. S. *Arkansas:*

Gale began on the 23d, wind SW. Lowest barometer 28.90 inches at 8 p. m. on the 24th, wind SW., 8, in latitude 54° 30′ N., longitude 30° W. End on the 26th, wind NW. Highest force of wind 11; shifts SW.-WSW.-W.-NW.

American S. S. *Chickasaw City:*

Gale began on the 25th, wind SW. Lowest barometer 28.40 inches at 4 p. m. on the 29th, wind WSW., 8, in latitude 51° 05′ N., longitude 21° 10′ W. End on the 30th, wind NW. Highest force of wind 10, N.; shifts S.-WSW.-N.-NE.

Belgian S. S. *Sunoco:*

Gale began on the 29th, wind W. Lowest barometer 28.73 inches at 1:30 a. m. on the 30th, wind SW., 10, in latitude 48° 34′ N., longitude 16° 53′ W. End on January 2, wind NW. Highest force of wind 11; shifts SW.-NNW.

British S. S. *Cornishman:*

Gale began on the 28th, wind NW. Lowest barometer 29.23 inches at noon on the 29th, wind NW., 10, in latitude 48° 16′ N., longitude 28° 01′ W. End on the 30th, wind NW. Highest force of wind 10, NW., steady from NW.

Dutch S. S. *Orestes:*

Gale began on the 27th, wind WNW., 7. Lowest barometer 28.92 inches at 2 p. m. on the 30th, wind SW., 10, in latitude 45° 17′ N., longitude 7° 18′ W. End on the 31st, wind NW., 6. Highest force of wind 11; shifts SW.-W.-WNW.-NW.

On the 21st and 22d there was a disturbance in the region between Bermuda and Hatteras that on the latter date began to move rapidly northeastward, as on the 23d the center was about 200 miles east of Nova Scotia. Storm logs follow.

American S. S. *Saugus:*

Gale began on the 21st, wind NE. Lowest barometer 29.53 inches at 9 a. m. on the 21st, wind NE., 9, in latitude 38° 03′ N., longitude 70° 11′ W. End on the 21st, wind NE. Highest force of wind 11; steady from NE.

American S. S. *Minnequa:*

Gale began on the 22d, wind SW. Lowest barometer 29.45 inches at noon on the 22d, wind WSW., in latitude 35° 10′ N., longitude 70° 10′ W. End on the 23d, wind NW. Highest force of wind 10; shifts WSW.-WNW.

Danish S. S. *United States:*

Gale began on the 23d, wind SW. Lowest barometer 28.60 inches at 7 a. m. on the 23d, wind SW., 9, in latitude 42° 30′ N., longitude 59° 40′ W. End on the 23d, wind WSW. Highest force of wind 11; shifts SW.-WSW.

Charts VIII to XI show the conditions from the 27th to 30th, inclusive. On the 27th there was an area of low pressure central near latitude 45° N., longitude 45° W.; this moved slowly eastward and later reinforced the eastern disturbance. Storm logs follow.

American S. S. *Minnequa:*

Gale began on the 26th, wind SE. Lowest barometer 29.65 inches at 6 p. m. on the 26th, wind S., in latitude 39° 18′ N., longitude 51° W. End on the 27th. Highest force of wind 10, S.; shifts SSE.-SSW.

American S. S. *Anaconda:*

Gale began on the 26th, wind S., 6. Lowest barometer 29.50 inches at 7 a. m. on the 27th, wind SW., 7, in latitude 43° 24′ N., longitude 45° 25′ W. End on the 30th, wind NW., 5. Highest force of wind 10, NW.; shifts S.-SW.-W.

NORTH PACIFIC OCEAN.

By WILLIS E. HURD.

Although stormy conditions, with snow and rain squalls, frequented the northern half of the ocean during December, there was much pleasant weather in middle and lower latitudes. At Honolulu the weather was more than usually delightful. The average hourly wind velocity at this station, 6.7 miles, was the lowest for the month during 19 years of record. Sunshine was considerably in excess of the normal, and the rainfall was the least, with the exception of that of December, 1913, in the record of the month for 36 years.

Up to the 23d of December, as indicated by the Japanese Weather Reports received at this writing, five cyclones from Asia entered the ocean after crossing the northern portion of Japan. In addition, as learned from ships' reports, storm conditions lay to the eastward of Japan as far as the 165th parallel of east longitude, for much of the remainder of the month, though they appear to have caused only moderate to strong gales. The first of the disturbances mentioned occasioned a heavy snowstorm with strong gales over the Archipelago and a great increase in the force of the northeast monsoon along the China coast on the 5th and 6th (Eastern time); and the fourth, that of December 15–16, with even more damaging gales and snowfall, more or less suspended railway traffic over the northern portion of Japan until the 18th. The other storms were of less importance.

During the same period three depressions, or minor cyclonic disturbances, appeared over more southern waters of the Far East. One, which originated to the eastward of Luzon on the 8th, moved northeastward

and passed the Bonin Islands on the 9th, apparently dying out or losing its identity shortly afterward in a cyclone then northeast of Japan. The other two originated near Taiwan on the 14th and 15th, respectively, and disappeared to the eastward or southeastward of Japan.

The continental cyclone which left the mainland on the 5th, developed great intensity east of Honshu, and several vessels reported snow squalls, storm to hurricane winds, and low pressures arising from it, during the 5th, 6th, and 7th of the month. After the 7th the storm moved into an extensive area of low pressure, then over the middle Aleutians, and its separate identity was lost. From point of wind velocity it seems to have been the most intense disturbance of December. On the 5th to 7th three Japanese steamships, eastward bound, experienced winds of force 11 to 12. The *Africa Maru*, in latitude 40° 54′ N., longitude 150° 25′ E., encountered a west-northwesterly hurricane about 10:30 a. m. of the 5th, lowest pressure 28.00 inches (uncorrected). The observer on board the *Yayoi Maru* wrote of the weather on the 6th:

Hurricane and tremendous sea. Barometer fell to 28.26 inches (corrected). Wind shifted from east to northwest slowly. Ship in danger and rolling heavily; lost her course. Highest wind force, 12 from northeast on the 7th, in latitude 48° 05′ N., longitude 158° 36′ E.

On the 6th the *Somedono Maru* experienced lowest pressure, 28.54 inches, in latitude 48° 05′ N., longitude 168° 25′ E.; highest force of wind, SW. 11.

The Japanese S. S. *Scotland Maru*, Captain Marui, Observer Kuwano, bound for Portland, Oreg., became involved on the 3d in a strong cyclone which was well at sea when the storm of the 5th was over Japan. At 6 a. m. of the 4th, in 46° 50′ N. 173° E., the vessel found herself in the center of the disturbance, "where," said the observer, "the waves were so violently confused that we were unable to maneuver the ship. Barometer showed 28.40 inches." Scarcely had this storm passed on than the *Scotland Maru* was caught in the advance winds of the Japanese disturbance, of which the observer noted:

Barometer dropped to 28.96 inches, and wind and waves were more severe than in previous storm.

From December 10 to 13 the Japanese S. S. *Somedono Maru* was steaming through its second storm encountered during the voyage to Tacoma. The highest observed wind velocity was 10 from the south, but the lowest barometric reading on that date was 27.86 inches (corrected), in latitude 50° N., longitude 169° 53′ W. The British S. S. *Shabonee* experienced this storm on the 11th, in latitude 43° 24′ N., longitude 163° 28′ W.; lowest barometer reading 28.74 inches (corrected); maximum wind velocity 10, SW.

The cyclone which blockaded northern Japan with snow on the 16th to 18th was apparently not so severe at sea as that of the 5th, yet no observations were received from near the storm center, and several vessels considerably south of it reported violent winds and tremendous seas. The Japanese S. S. *Seiyo Maru*, Yokohama toward San Francisco, while in latitude 30° 36′ N., longitude 151° 10′ E., encountered a gale from NNW. to W., force 11, lowest pressure 29.55 inches, on the 16th. On the same date the American S. S. *Meigs*, in latitude 33° 12′ N., longitude 150° 50′ E., experienced "westerly wind reaching force 10 and probably stronger, and phenomenal sea, approximate height, 50 feet." The lowest pressure recorded was 29.35 inches. On the 16th also the British S. S. *Achilles*, from Hongkong toward Victoria, was beset by a north-northwesterly gale, lowest pressure 29.35 inches, in latitude 37° N., longitude 144° 17′ E.

For the entire North Pacific, taking into consideration the traveling cyclones and the more or less violent pulsations of the Aleutian LOW, the stormiest part of the ocean was that west of the 180th meridian.

From the 8th until the 12th a storm area lay between Honolulu and San Francisco. It remained nearly stationary midway between these two points until about the 12th, when it moved rapidly eastward, passing inland over central California. On the 11th, when the storm was apparently at its peak, the American S. S. *Manoa* was in a northwest gale, force 10, pressure 29.48 inches, near latitude 29° N., longitude 145° W.

Other storms or depressions at various times entering our western coasts during the month were evidently extensions of or offshoots from the Aleutian LOW, and mostly occurred north of the United States. The dates of such entries were the 6th, 10th, 21st, 24th, 27th, and 31st.

The Aleutian LOW was generally in evidence. In the Gulf of Alaska and southward roughly to the 40th or 45th parallel, it was well developed from the 1st to the 10th, on the 17th and 18th, and from the 23d to the 31st. During the last period especially vessels traversing the area experienced rough weather, though reported gales did not exceed 10 in force until the 31st, when a 70-mile wind was reported off the coast below Seattle. During other portions of the month the LOW's center of activity was much to the westward, there occasionally spreading southward to and even beyond Midway Island.

The North Pacific HIGH was fairly well developed until about the 8th, when it narrowed to a shallow band extending from Lower California westward to beyond Hawaii. It remained shallow and irregular in area until the 15th, when it assumed more control of the weather over the eastern part of the ocean south of the 40th parallel, but did not present its normal strength until the 28th to 31st, when it lay off the California coast with a crest of 30.20 to 30.30 inches.

Pressure over the eastern portion of the ocean, as determined from observations at the island stations, averaged below normal. At Dutch Harbor the mean for the month, based on p. m. observations, was 29.40 inches, or about 0.15 inch below normal. The change from the preceding month was approximately −0.20 inch. The highest pressure recorded was 30.10, on the 1st; the lowest, 28.64, on the 11th. At Midway Island the deficiency was relatively greater than at Dutch Harbor, being 0.14 inch. The normal for December is 30.02 inches. Readings above normal were recorded on only four days. The lowest pressure, 29.70, occurred on the 17th; the highest, 30.16, on the 31st. At Honolulu conditions were about the reverse of those at Midway, pressure being above normal almost continuously. The average for the month was 30.07 inches, an excess of some 0.05 inch. The highest reading, 30.16, was recorded on the 24th; the lowest, 29.92, on the 15th.

Fog was observed by steamers traveling the northern route during two periods, namely: From the 1st to the 4th, and from the 10th to the 20th. All occurrences were noted east of the 180th meridian. During the first period the phenomenon was mostly observed near the 50th parallel, except along the coast, where it was seen at least as far south as latitude 38° N. During the second period fog was more widespread, and on the 11th and 12th had an observed southern limit near San Pedro.

DISTURBANCES IN SOUTHERN WATERS DURING THE HURRICANE SEASON OF 1922.

By W. P. DAY.

Air pressure was abnormally high in the region of the subpermanent north Atlantic anticyclone during the forepart of the hurricane season (including August) with a tendency to displace the line of discontinuity between the two trade-wind systems (along which these storms develop) to a more southern latitude. This may possibly account for the fact that only two, or possibly three, typical hurricanes were noted in Atlantic waters, while the unusual number of five were encountered in the Pacific to the south and west of the Mexican coast. The latter have been charted and described by Mr. Willis E. Hurd of the Marine Division in an unpublished manuscript entitled "Tropical Storms of the Eastern North Pacific Ocean." At least two of the storms charted by Hurd can be connected with disturbances moving westward over the extreme southern Caribbean.

On June 12 disturbed conditions were noted over the western Caribbean. Moving northwest across the Yucatan Peninsula, the disturbance gained considerable intensity and the characteristics of a developing hurricane in the southwestern Gulf of Mexico. A further increase in intensity was prevented by its passage inland on the Mexican coast between Tampico and the mouth of the Rio Grande, but not without first causing unusually heavy rains over the lower Rio Grande Valley. (Consult also Chart XII at back of this REVIEW.)

After a long period of relative quiet a series of disturbances had their beginning about August 23. Unsettled conditions were noted in the extreme southern Caribbean just north of Panama, then rains in Central America and southern Mexico, and finally a hurricane was noted by Hurd in the Pacific Ocean on the 27th near lat. 15° N. and long. 100° W. (lowest reported barometer reading 29.31 inches). The next of this series was noted as a disturbance over the western Caribbean on the 26th, and moved slowly across Central America and along the extreme Mexican coast. This was also charted by Hurd on September 1 near lat. 17° N. and long. 103° W., having developed hurricane intensity over the Pacific Ocean (lowest reported barometer reading 29.35 inches). Hurd also describes a very formidable hurricane in the vicinity of the Revillo Gigedo Islands, reported by the S. S. *Bessemer City*, on the 9th and 10th of September (lowest reported barometer reading 27.96 inches).

The next period began with the reporting of a fully developed hurricane to the east of the Windward Islands. Moving northwest, this storm passed near Barbuda of the Leeward group on the morning of the 16th of September (lowest barometer reading 28.58 inches). After recurving the huricane passed near Bermuda on the morning of the 21st (lowest barometer reading 28.57 inches), continued northeastward into the steamer lanes and was encountered by a large number of vessels before reaching the English coast in a modified form. From a very intense storm of small diameter, which was noted at Barbuda and Bermuda, the storm enlarged its area enormously in the northern latitudes and retained much of its vortical energy. A most unusual condition prevailed while this storm was recurving in the vicinity of Bermuda. A very severe Atlantic coast storm developed in the Gulf of Charleston in connection with an area of high barometric pressure over the Lake region and the New England States, reached its greatest intensity off Hatteras on the 20th and 21st, and died out with the dissipation of the northern high-pressure area. This storm was not a hurricane, though winds of near hurricane force were reported on its northern quarter, where the isobars were constricted. No barometer readings lower than 29.50 inches were reported, and, in fact, there was no unusual gradient near the center. The astonishing thing is in the coexistence of this large extra-tropical cyclone with the almost minute (comparatively) but extremely intense hurricane on its eastern periphery, the subsequent filling up of the coast storm, and the enormous expansion of the hurricane.

Unsettled weather prevailed over the Gulf of Mexico and the western Caribbean during much of the month of October. Several disturbances were charted within this area, but only one attained hurricane intensity or characteristics. The first of these was noted as a slight disturbance in the northwestern Caribbean on the 12th and moved northwest and north without gaining any great intensity, a sort of abortive hurricane, passing inland on the Gulf coast between Mobile and Pensacola on the 17th. On the 14th, falling barometer, wind shifts, and squally weather were reported by a vessel immediately southwest of Jamaica. In contrast to the preceding disturbance, this storm developed rapidly both in intensity and area, becoming a severe hurricane by the 16th. Moving at first west-northwest it crossed the Yucatan Peninsula, was deflected to the southwest by rising pressure on its northwestern quarter, and was last charted on the 21st, decreased in energy and modified in form after its passage across land areas, in the vicinity of Frontera in the Province of Tabasco, Mexico. Hurd has charted a hurricane near Cape San Lucas in the Pacific on the 15th of the month, which may belong to this last series.

CYCLONE OF THE ARABIAN SEA.

On the 2d to 5th of December, 1922, a tropical cyclone of considerable intensity traversed the Arabian Sea. The American S. S. *Eclipse*, Capt. M. Hawkins, encountered the full force of its storm winds. He said: "I did not realize that it was a revolving storm until after 4 p. m., December 2, as it had all the usual squally weather and conditions that are experienced before getting into the NE. monsoon." The *Eclipse* was then near latitude 9° 48′ N., longitude 70° E., with wind NE. x E., force 9, pressure 29.34 inches. Four hours later, in latitude 9° 50′ N., longitude 69° 20′ E., the vessel was in a NNE. hurricane, pressure 28.20 inches. From 8:05 p. m. until 8:30 p. m. it was in the storm center, with light airs. From 8:30 p. m. until 8:55 p. m. hurricane winds from the south were experienced, during which time the pressure rose from an observed minimum of 28.20 inches to 29.00 inches. The storm then receded rapidly.

On December 5 the American S. S. *Algic*, Capt. Charles Olsen, Port Said toward Bombay, was slightly involved in this storm in latitude 15° 42′ N., longitude 57° 18′ E. This vessel reported a steady NE. gale, highest force 7, lowest pressure 29.84 inches; also a heavy SE. swell which continued for about 20 hours after the cessation of the NE. wind. Bombay at this time reported the cyclone to be in about 16° N., 64° E., moving WNW. or dissipating.— *W. E. Hurd.*

NOTES ON WEATHER IN OTHER PARTS OF THE WORLD.

North Atlantic.—WASHINGTON, D. C., Dec. 10.—Emergency orders to beware of enormous icebergs were flashed to all trans-Altantic shipping by the Naval Hydrographic Office yesterday. All vessels were advised to take the summer lanes immediately. Ordinarily the summer lanes are not used until about February 1. Great masses of ice, however, are already floating through the winter lanes, constituting a grave menace to shipping.—*Washington Times, Dec. 10, 1922.*

PLYMOUTH, ENGLAND, Dec. 31.—The American steamship *President Harding* arrived here to-day from New York. During the voyage the vessel encountered four days of gales with tremendous seas.—*New York Times, Jan. 1, 1923.*

France.—PERPIGNAN, Dec. 7.—A train was blown off the track near the Fitou station yesterday by a mistral of great violence.—*Binghamton Press, Dec. 7, 1922.*

Italy.—ROME, Dec. 13.—Italy is suffering from an exceptional cold wave. Five persons were frozen to death in Rome last night and several similar cases are reported from other cities.

The Appenine Mountains are completely covered with snow. Wolves driven desperate by the lack of food have descended to the plains and are seen almost at the gates of the capital.—*Washington Times, Dec. 13, 1922.*

Greece.—ATHENS, Dec. 14.—The Orient Express, due in Athens Monday evening, has been snowed in by a blizzard in the Macedonian Mountains for the last 24 hours. Three feet of snow have fallen in the mountain districts, and trains that should have left that city for the north are being detained here.—*New York Post, Dec. 14, 1922.*

Japan.—TSURUGA, Dec. 2.—While the great majority of farmers of Japan have had a prosperous year with bountiful crops, those in Asaigun, Shiga prefecture, in the center of which is Lake Biwa, have been impoverished, the long drought having destroyed their crops.—*Chicago Evening Post, Dec. 26, 1922.*

DETAILS OF THE WEATHER IN THE UNITED STATES.

GENERAL CONDITIONS.

The outstanding feature of December weather was the rapid east-southeastward movement of at least four great anticyclones from the Canadian Northwest to the Atlantic. The movements took place during the following named dates:

The first, 4th to 7th, inclusive.
The second, 8th to 12th, inclusive.
The third, 10th to 14th, inclusive.
The fourth, 15th to 19th, inclusive.

On the date last named an anticyclone occupied the Great Basin region; it persisted practically until the end of the month and during that time the movement of anticyclones from the Canadian Northwest ceased and cyclones entered the continent generally south of the mouth of the Columbia River.

An unusually large number of cyclones (24) was observed during the month.

The drought in eastern sections that had prevailed since September was terminated.

CYCLONES AND ANTICYCLONES.

By W. P. DAY.

The number of low-pressure areas greatly exceeded the normal and generally speaking the day-to-day movement was also above the normal. High-pressure areas were mostly of the Alberta type, moving in paths somewhat farther north than is usual during December. There were no abnormal developments, except a storm of the Colorado type which moved eastward and passed off the Virginia Capes into the Atlantic, causing whole gales from the northeast on the New England coast. The number of cyclones (LOWS) and anticyclones (HIGHS) by types follows:

CYCLONES.	Alberta.	North Pacific.	South Pacific.	Northern Rocky Mountain.	Colorado.	Texas.	East Gulf.	South Atlantic.	Central.	Total.
December, 1922	6.0	6.0	1.0	......	6.0	1.0	......	4.0	......	24.0
Average number, 1892–1912, inclusive	4.3	2.5	0.8	0.3	1.1	2.5	0.2	0.3	0.4	12.4

ANTICYCLONES.	North Pacific.	South Pacific.	Alberta.	Plateau and Rocky Mountain region.	Hudson Bay.	Total.
December, 1922	......	2.0	6.0	2.0	1.0	11.0
Average number, 1892–1912, inclusive	1.1	1.2	4.7	1.3	0.5	8.8

FREE-AIR CONDITIONS.

By W. R. GREGG, Meteorologist.

Free-air conditions for the month of December were in general not far from normal. As indicated in Table 1, temperatures were somewhat below normal at Ellendale, N. Dak., and above at Groesbeck, Tex. In both cases smaller departures prevailed in the upper than in the lower levels. At intermediate stations temperatures were very close to normal, variations as a rule amounting to less than 1° C. The latitudinal distribution above indicated agrees well with the conditions shown in Climatological Chart III, viz, negative departures along the northern border and positive along the southern, with nearly normal temperatures over a fairly wide belt between these two regions. Although departures from normal for the month as a whole were not large in any part of the country, it should be noted that the averages are based upon individual values which vary between rather wide extremes, the usual case at this time of year,

particularly in the Northern States. During this month, for example, abnormally low temperatures prevailed in the Northwest, Montana, the Dakotas, etc., from about the 5th to the 18th. The effect of these low temperatures upon the monthly mean was largely overcome by the succeeding warm spell. Similarly, in the South, especially in Texas and adjoining States, abnormally high temperatures prevailed in the first part of the month, although extremes in this part of the country were not as great, nor are they ever as great, as in the northern part. These wide departures are reflected in part, never completely, in the upper levels. Thus, during the Northwest cold spell free-air temperatures up to 2 or 3 kilometers above Ellendale were almost always higher than were those at the surface; on the other hand the lapse rate above Groesbeck during the warm spell in the South was considerably above (almost double) its normal value. In general, then, temperatures in the free-air depart less widely from the mean than do those at and near the surface.

In connection with the kite flight at Broken Arrow on the afternoon of the 4th, the observer submits the following note:

Before this flight was started a line of cumulus-topped clouds was noted above the northwestern horizon, denoting the approach of a windshift line. It was decided to make the flight and have it over before the line reached the station. However the wind shift was only a few miles away when reeling in was begun at 3:38 p. m. and it passed overhead at 3:55 p. m. while two kites were still in the air. The line extended from northeast to southwest and from horizon to horizon. It consisted of a dark roll of St.-Cu. followed by lighter St.-Cu. Considerable turbulence was noted in the clouds at the wind-shift line and some rolling about a horizontal axis.

This condition may be considered a very good example of the "squall line" as developed by the Bjerknes hypothesis. There is evidence of a south component in the wind at higher elevations after the direction at the surface and lowest levels had become northwesterly. The kite flight of the following morning (5th) indicated, as a result of this south component, a higher temperature at the greatest altitude reached (1,817 m.) than at the surface.

At Groesbeck, on the morning of the 15th, the temperature at 1,000 m. above the ground was 15° C. higher than at the surface. Such a large inversion in this latitude is very uncommon, and it is of interest to note that the warm air found at this height above the surface is not the result of nocturnal radiation but, instead, a consequence of air importation. On this occasion the temperature of the air on the 14th, the day previous, at 1,000 m. was maintained during the following night, as there was a strong south component persisting in the upper winds throughout this period.

Relative humidities and vapor pressures differed little from the normal, except that a considerable excess in vapor pressure prevailed in the lower levels at Groesbeck, due to the fairly high temperatures that prevailed at that station.

As indicated in Table 2, resultant winds for the month were on the whole close to normal, except in the lowest levels at Broken Arrow and Due West. The agreement in directions is especially close. Velocities were somewhat above normal at Drexel, Ellendale, and Royal Center, but the difference is generally less than 3 m. p. s.

Wind velocities of 40 m. p. s. or more were observed as follows:

Station.	Date.	Velocity.	Direction.	Altitude
		m. p. s.		*m.*
Aberdeen, Md	Sept. 5	41	WNW.	3,100
Do.	Sept. 13	44	WNW.	4,200
Dahlgren, Va.	Sept. 6	40	WNW.	5,000
Drexel, Nebr	Sept. 12	42	WNW.	4,100
Do.	Sept. 24	45	NW.	3,700
Due West, S. C.	Sept. 22	43	NW.	5,500
Ellendale, N. Dak	Sept. 13	40	W.	4,600
Do.	Sept. 17	40	WNW.	5,000
Do.	Sept. 24	40	NW.	4,000
Mitchel Field, N. Y	Sept. 16	43	W.	3,400
Do.	Sept. 19	40	WNW.	3,200
Do.	Sept. 29	45	N.	2,700
Royal Center, Ind	Sept. 5	48	WNW.	4,200
Washington, D. C	Sept. 6	44	NW.	3,300

At this season of the year easterly winds rarely occur in the upper levels, i. e., above 4 or 5 kilometers. In the present month no such winds were observed in northern or central latitudes. They did occur, however, in the Southern States, as follows:

Groesbeck, Tex., on the 19th, and
Key West, Fla., on the 13th and 17th.

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during December, 1922.*

TEMPERATURE (° C.).

Altitude, m. s. l. (*m.*)	Broken Arrow, Okla. (233*m.*)		Drexel, Nebr. (396*m.*)		Due West, S. C. (217*m.*)		Ellendale, N. Dak. (444*m.*)		Groesbeck, Tex. (141*m.*)		Royal Center, Ind. (225*m.*)	
	Mean.	Departure from 5-year mean.	Mean.	Departure from 8-year mean.	Mean.	Departure from 2-year mean.	Mean.	Departure from 5-year mean.	Mean.	Departure from 5-year mean.	Mean.	Departure from 5-year mean.
Surface	5.8	+0.3	−3.8	+0.3	8.0	−0.6	−11.1	−2.9	13.3	+3.9	−1.8	−0.4
250	5.8	+0.3	......	......	7.9	−0.6	......	......	13.0	+2.8	−1.9	−0.4
500	5.1	+0.2	−3.9	+0.1	7.7	−0.3	−10.9	−2.9	12.3	+2.5	−3.0	−0.4
750	4.4	−0.4	−3.6	−0.1	7.7	0.0	−10.2	−3.0	11.9	+2.3	−2.5	+0.5
1,000	4.8	−0.6	−2.4	+0.2	7.5	+0.1	−9.4	−3.2	11.7	+2.2	−1.9	+1.0
1,250	5.2	−0.3	−1.7	+0.4	7.2	+0.4	−8.9	−3.2	11.2	+2.2	−2.1	+0.9
1,500	5.2	+0.1	−1.7	+0.6	6.2	+0.4	−8.4	−2.7	10.3	+2.0	−2.3	+0.8
2,000	3.8	+0.4	−2.8	+1.0	4.2	+0.1	−9.4	−2.4	7.9	+1.3	−4.3	+0.1
2,500	1.4	+0.3	−5.6	+0.5	1.7	−0.3	−11.4	−2.2	5.8	+1.4	−6.5	−0.1
3,000	−1.2	+0.2	−8.2	+0.4	−0.1	+0.2	−13.0	−1.1	3.2	+1.3	−9.1	−0.4
3,500	−4.0	0.0	−11.0	+0.2	−0.9	+1.4	−16.0	−2.3	0.4	+1.3	−12.7	−1.2
4,000	−6.8	0.0	−13.4	+0.6	−3.3	+2.0	−18.3	−1.7	−2.3	+1.3	−16.3	−1.4
4,500	−9.2	+0.4	−17.6	−0.6	......	......	......	......	−4.9	+0.9	......	......
5,000	−13.7	−0.1	......	......	......	......	......	......	−7.4	+1.0	......	......

RELATIVE HUMIDITY (%).

Altitude, m. s. l. (*m.*)	Broken Arrow Mean	Dep.	Drexel Mean	Dep.	Due West Mean	Dep.	Ellendale Mean	Dep.	Groesbeck Mean	Dep.	Royal Center Mean	Dep.
Surface	65	−5	77	−7	81	+0	86	+3	69	−4	70	0
250	65	−5	......	......	80	+6	......	......	69	−2	78	−1
500	62	−2	68	−6	73	+5	84	+3	69	+3	72	−3
750	62	+3	60	−7	68	+4	76	+2	67	+5	62	−8
1,000	57	+6	56	−5	66	+5	70	+3	61	+5	54	−9
1,250	51	+5	53	−3	66	+7	66	+4	56	+5	50	−7
1,500	46	+3	52	−2	65	+7	63	+4	52	+5	48	−5
2,000	42	+3	49	−3	60	+6	61	+5	44	+5	40	0
2,500	42	+4	40	−3	57	+9	60	+3	35	+1	50	+2
3,000	42	+4	45	−7	47	+5	50	+1	29	−2	50	+2
3,500	44	+6	43	−9	44	+3	61	+3	26	−3	58	+7
4,000	45	+7	39	−13	46	+4	59	+4	24	−5	66	+12
4,500	46	+7	43	−11	......	......	......	......	23	−5	......	......
5,000	47	+7	......	......	......	......	......	......	23	−5	......	......

VAPOR PRESSURE (*mb.*).

Altitude, m. s. l. (*m.*)	Broken Arrow Mean	Dep.	Drexel Mean	Dep.	Due West Mean	Dep.	Ellendale Mean	Dep.	Groesbeck Mean	Dep.	Royal Center Mean	Dep.
Surface	6.54	−0.14	3.32	−0.40	9.41	+0.55	2.56	−0.43	11.51	+1.59	4.38	−0.26
250	6.49	−0.13	......	......	9.27	+0.55	......	......	11.27	+1.67	4.29	−0.29
500	5.96	+0.17	3.14	−0.42	8.34	+0.52	2.51	−0.44	10.63	+1.87	3.63	−0.37
750	5.62	+0.45	2.85	−0.45	7.81	+0.56	2.35	−0.42	9.96	+2.03	3.23	−0.33
1,000	5.14	+0.65	2.84	−0.29	7.31	+0.61	2.29	−0.34	8.82	+1.90	2.97	−0.23
1,250	4.56	+0.56	2.85	−0.08	6.99	+0.80	2.24	−0.29	7.73	+1.70	2.79	−0.10
1,500	4.08	+0.52	2.75	+0.02	6.30	+0.72	2.17	−0.19	6.62	+1.47	2.66	+0.02
2,000	3.42	+0.52	2.37	+0.07	5.07	+0.50	1.98	−0.01	4.48	+0.85	2.33	+0.19
2,500	2.91	+0.50	1.93	−0.03	4.01	+0.51	1.68	−0.01	2.75	+0.11	2.01	+0.23
3,000	2.49	+0 40	1.46	−0.15	3.01	+0.28	1.29	−0.07	1.75	−0.30	1.61	+0.15
3,500	2.20	+0.38	1.09	−0.21	2.70	+0.41	0.95	−0.10	1.23	−0.31	1.25	−0.02
4,000	1.92	+0.28	0.58	−0.39	2.62	+0.84	0.80	+0.04	0.97	−0.34	0.93	−0.11
4,500	1.83	+0.27	0.42	−0.23	......	......	......	......	0.80	−0.31	......	......
5,000	1.69	+0.22	......	......	......	......	......	......	0.71	−0.23	......	......

TABLE 2.—*Free-air resultant winds (m. p. s.) during December, 1922.*

Altitude, m. s. l. (m.)	Broken Arrow, Okla. (233m.)				Drexel, Nebr. (396m.)				Due West, S. C. (217m.)			
	Mean.		5-year mean.		Mean.		8-year mean.		Mean.		2-year mean.	
	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.
Surface	N. 49° W.	1.7	S. 60° W.	1.2	S. 48° W.	1.5	W.	1.1	N. 87° E.	0.6	S. 62° W.	0.9
250	N. 46° W.	1.7	S. 52° W.	1.3	....	....	....	....	N. 88° E.	0.6	S. 60° W.	1.1
500	S. 43° W.	1.3	S. 43° W.	3.4	S. 66° W.	2.4	N. 88° W.	1.8	S. 34° W.	1.1	S. 67° W.	3.3
750	S. 53° W.	2.0	S. 48° W.	4.3	N. 89° W.	4.1	N. 74° W.	3.5	S. 64° W.	2.5	S. 76° W.	5.0
1,000	S. 64° W.	2.5	S. 60° W.	4.5	S. 85° W.	5.5	N. 75° W.	5.2	S. 61° W.	3.3	S. 82° W.	6.1
1,250	S. 72° W.	3.2	S. 77° W.	4.8	N. 89° W.	7.2	N. 76° W.	5.4	S. 61° W.	4.9	S. 81° W.	6.7
1,500	S. 77° W.	4.0	S. 82° W.	5.2	N. 87° W.	9.2	N. 78° W.	6.9	S. 63° W.	6.2	W.	8.3
2,000	S. 76° W.	6.1	S. 86° W.	6.9	N. 87° W.	11.8	N. 79° W.	8.8	S. 66° W.	8.3	N. 88° W.	8.9
2,500	S. 84° W.	8.1	N. 89° W.	9.6	N. 84° W.	13.8	N. 79° W.	11.4	S. 81° W.	9.8	N. 82° W.	12.6
3,000	S. 86° W.	9.9	N. 86° W.	11.6	N. 82° W.	15.6	N. 80° W.	13.4	S. 86° W.	14.8	N. 85° W.	15.0
3,500	N. 84° W.	9.9	N. 84° W.	12.8	N. 76° W.	17.3	N. 84° W.	15.2	S. 80° W.	14.4	N. 88° W.	13.7
4,000	N. 88° W.	7.1	N. 82° W.	10.9	N. 76° W.	18.8	N. 86° W.	17.0	N. 82° W.	12.5	N. 78° W.	12.5
4,500	N. 78° W.	10.5	N. 79° W.	13.1	N. 68° W.	19.9	N. 72° W.	18.4	....	....	N. 70° W.	13.2
5,000	S. 68° W.	14.9	N. 88° W.	14.7	N. 68° W.	20.8	N. 78° W.	17.7	....	....	N. 68° W.	12.5

Altitude, m. s. l. (m.)	Ellendale, N. Dak. (444m.)				Groesbeck, Tex. (141m.)				Royal Center, Ind. (225m.)			
	Mean.		5-year mean.		Mean.		5-year mean.		Mean.		5-year mean.	
	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.
Surface	N. 71° W.	3.7	N. 54° W.	3.4	S. 55° W.	2.2	S. 86° W.	1.2	S. 34° W.	1.2	S. 50° W.	2.1
250	....	....	....	....	S. 51° W.	2.7	S. 62° W.	1.6	S. 26° W.	1.9	S. 50° W.	2.4
500	N. 76° W.	4.4	N. 61° W.	3.7	S. 50° W.	4.2	S. 50° W.	3.2	S. 59° W.	4.5	S. 57° W.	5.0
750	N. 75° W.	6.4	N. 60° W.	5.7	S. 55° W.	5.4	S. 52° W.	4.8	S. 72° W.	7.0	S. 66° W.	6.6
1,000	N. 69° W.	8.9	N. 58° W.	6.8	S. 56° W.	5.9	S. 52° W.	5.8	W.	7.9	S. 79° W.	7.8
1,250	N. 66° W.	10.0	N. 56° W.	7.6	S. 59° W.	6.6	S. 60° W.	6.6	S. 86° W.	10.6	S. 83° W.	9.8
1,500	N. 65° W.	11.2	N. 58° W.	8.9	S. 63° W.	8.3	S. 64° W.	7.4	W.	13.1	S. 88° W.	11.0
2,000	N. 66° W.	13.6	N. 60° W.	10.1	S. 67° W.	8.2	S. 70° W.	8.6	N. 89° W.	14.7	N. 89° W.	12.3
2,500	N. 69° W.	15.9	N. 65° W.	12.2	S. 70° W.	9.7	S. 75° W.	10.0	N. 80° W.	16.9	N. 87° W.	13.3
3,000	N. 72° W.	16.9	N. 70° W.	13.7	S. 70° W.	12.2	S. 72° W.	11.6	N. 86° W.	16.8	S. 87° W.	13.8
3,500	N. 77° W.	19.2	N. 79° W.	15.0	S. 73° W.	12.2	S. 74° W.	11.9	N. 72° W.	14.0	S. 84° W.	11.2
4,000	N. 80° W.	20.0	N. 79° W.	14.8	S. 68° W.	12.8	S. 73° W.	11.4	S. 68° W.	18.6	S. 74° W.	12.7
4,500	....	....	S. 73° W.	16.2	S. 74° W.	11.2	N. 89° W.	11.2	....	....	....	....
5,000	....	....	S. 77° W.	15.3	S. 78° W.	13.4	N. 84° W.	13.6	....	....	....	....

THE WEATHER ELEMENTS.

By P. C. DAY, Meteorologist, in Charge of Division.

PRESSURE AND WINDS.

The distribution of the average sea-level pressure during December, 1922, presented some features not frequently observed on charts of similar character for that month in other years, notably the extensive displacement of the high area normal to the Southeastern States in winter which, during the present month, had an unusual extension into the New England States, due to the southward movement of high-pressure areas from the Hudson Bay territory, a condition infrequently experienced so early in the winter. Also the Plateau high pressure, which usually persists with much strength, was materially weakened, and occupied a position well south of that usual to the period of the year. This weakening and displacement were due mainly to the persistence of high pressure over southeastern Alaska, forcing the winter cyclones of that region inland at points farther south than usual, particularly during the early portion of the month. Finally, the lowering of the average pressure, normally only feebly apparent, along the eastern slope of the Rocky Mountains was much more fully developed than usual.

The changes in atmospheric pressure during December, 1922, as compared with the preceding month, likewise exhibited distinct departures from those usually prevailing. Under normal conditions pressure in December increases over that for November in all portions of the United States save in New England and the far Northwest, where, due to more stormy conditions, it is usually distinctly less. During the current month this was reversed as to eastern districts, where the pressure was distinctly higher than in November, while in the Northwest the area of decreased pressure was greatly extended and the decreases far greater than normal.

Due to the rapid movement of cyclones and anticyclones across the country, the atmospheric circulation was much complicated, the prevailing wind directions frequently differed greatly at near-by points, and no extensive areas had winds closely conforming to the indications of the pressure gradients.

Some high winds occurred over the north Pacific coast districts during the early part of the month and again near the end, and the cyclonic storm that moved northeasterly from the middle Mississippi Valley to southern New England from the 27th to 29th was attended by gales and high winds over the middle and north Atlantic coasts.

A tabular statement of the main facts concerning the damaging storms of the month follows at the end of this section.

TEMPERATURE.

December as a whole experienced marked variations of temperature for different periods of the month and for the various portions of the country.

The first few days were decidedly warm in most sections of the South from Texas eastward, and warmth to a somewhat less degree was experienced over the entire country east of the Rocky Mountains, save over Montana and portions of North Dakota. Here, particularly in northern Montana, severe cold was experienced and the period was moderately cold over most of the country to westward of the Rocky Mountains.

During the period from the 5th to 12th severe cold continued in Montana and adjacent States and to the westward of the Rocky Mountains, and extended over the northern and portions of the central districts to New England. In portions of Montana this week was from 25 to 30 degrees colder than is usually observed in December. This period continued moderately warm in most southern, and portions of the central, districts.

The week ending the 19th continued cold over all northern districts, the temperatures along or near the northern border ranging from 20 to 30 degrees below normal; in western Montana some of the lowest temperatures ever observed in December were reported. The cold weather extended southward over the Great Plains to the Rio Grande and into most of the eastern districts, the weather continuing moderately warm, however, over the East Gulf and South Atlantic States; the week was moderately warm in the far Southwest.

The period from the 19th to 26th experienced a remarkable rise in temperature over the Northwestern States. There was a very general warming up over nearly all parts of the country, except that severe cold continued during the first few days in the Northeastern States. The last few days were notably warm, particularly about Christmas, and that day was the warmest ever known in many portions of the central valleys and Great Plains.

The last few days of the month continued moderately warm over most districts, although there were sharp falls in temperature over the Northeastern States on the 26th and 27th, and the weather was cold along the Atlantic coast on the 29th and 30th.

The month as a whole was colder than normal over all northern portions of the country and in Canada as well,

save for a small area in Ontario, just eastward of Lake Huron; there the monthly averages were slightly higher than normal. In portions of Montana, Idaho, and adjacent States, the month was among the coldest of record, and in certain localities severe cold persisted for an unusually long period.

In the southern districts the average temperatures were mainly warmer than normal and in portions of the Gulf States it was a particularly warm and delightful month.

The maxium temperatures of the month were observed during the first decade over all districts from the Mississippi Valley eastward and in portions of Texas and adjoining States, and the far Northwest. Over the middle and northern Great Plains and most of the western Mountain States they were observed mainly during the last decade, at which time some of the highest temperatures ever observed in December were reported.

The lowest temperatures of the month were observed mainly during the last two decades, although the coldest weather of the month in Oregon and California occurred on the 8th. While record-breaking low temperatures were confined only to portions of western Montana, minimum temperatures nearly as low as ever before observed were reported from several localities in the northern Rocky Mountains.

PRECIPITATION.

Rains were frequent and generous in amount over the States from the middle and lower Mississippi Valley eastward to the coast where the monthly amounts were usually well above the normal. Over the Atlantic States to the northward of Maryland precipitation was mostly less than normal, but usually sufficient to relieve to a considerable extent the severe water shortage that had resulted from the semidroughts that had persisted for considerable periods in many parts of those States. In some sections of eastern Pennsylvania the water supply at the close of the month was still insufficient for present needs, due to the long period of deficient precipitation which for the year as a whole was the greatest in a hundred years or more.

Precipitation was mostly light, and materially less than normal over a wide area extending from the upper Lakes southwesterly to the Rio Grande Valley and Arizona. In portions of this area, particularly in Iowa, and locally in adjacent States, the total precipitation for the month was the least or nearly the least ever reported in December.

From the central and northern Rocky Mountains westward to the Pacific precipitation was mainly above normal, and markedly so over most of California where precipitation was frequent and at times heavy. Farther north over Oregon and Washington precipitation was frequent, particularly during the first half of the month, but the totals were usually not greatly in excess of the normal.

The principal periods with heavy precipitation over considerable areas in the districts from the Mississippi Valley eastward were: The 7th to 9th, over most States from the Mississippi Valley eastward, covering a wide area with either rain or snow, but the amounts were usually not heavy; 14th to 15th, heavy precipitation in the lower Ohio Valley and Tennessee; 16th and 17th, in the Middle Gulf States and lower Ohio Valley; 19th in the East Gulf States; 21st in the South Atlantic States; 27th to 29th over the Gulf States, Ohio Valley, and Atlantic Coast States; 27th to 28th from central California northward; and on the 31st in the far Northwest.

SNOWFALL.

During the first 10 days of December considerable snow fell in the northern portions of the country from the Cascade Mountains eastward to Minnesota, especially in Montana and the high districts to the westward.

From the 13th to 17th considerable snow fell from the middle Plateau eastward to the western Plains region, and moderate amounts from Iowa eastward. On the 28th and 29th snow occurred from the Great Lakes eastward, with heavy falls in New York and New England.

At the end of the month the appreciable snow-covered area was confined mainly to New York and New England, the upper Lakes and thence westward to Montana, and at the higher elevations of the central and northern mountain States. In the high Sierra of California deep snow had accumulated, the depth approximating 100 inches at elevations of 7,000 feet, and there were greater depths at higher elevations. Deep snow had also accumulated in some of the high mountains of Colorado, Idaho, and Wyoming.

The distribution of the total snowfall of the month is shown on Chart VII of this issue.

RELATIVE HUMIDITY.

The relative humidity of the atmosphere showed some marked departures from the normal over small areas, particularly in Arizona and other portions of the Plateau region and southern California, where the percentages ranged from 10 to 25 per cent above the normal. In the Atlantic and Gulf States the percentages were likewise well above the normal, and also in the Dakotas. Elsewhere the relative humidity was usually below the normal though the departures were mainly small.

SEVERE LOCAL STORMS.

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the Annual Report of the Chief of Bureau.]

Place.	Date.	Time.	Width of path (yards).	Loss of life.	Value of property destroyed.	Character of storm.	Remarks.	Authority.
Chicago, Ill., and Great Lakes region.	5-6					Wind	Lake traffic tied up. Three vessels reported missing, others forced to seek shelter. Heavy damage at Sault Ste. Marie.	Times (Washington, D. C.); Star (Oneonta, N. Y.).
Jefferson, Tex.	7	5-7 a. m.			$5,000	Electrical and rain, followed by small tornado.	Wind damaged roof of post office and unroofed several buildings.	Times Herald (Dallas, Tex.).
Lake Oneida, N. Y.	5				150,000	High winds	5 barges and some 50,000 bushels of wheat destroyed.	Official, U. S. Weather Bureau.
Lizard Island (75 miles north of Point Aux Pins, Ont.).	13			27?		do	Tug Reliance wrecked on rocks. 27 persons reported missing. Survivors exposed to severe cold.	Post; Herald (Washington, D. C.).
Tullahoma, Tenn.	14-15					Thunderstorm	A number of houses were blown from foundations and 2 barns destroyed. Loss estimated at thousands.	Official, U. S. Weather Bureau.
Port Arthur, Tex.	26	7:25 p. m.	30-50		10,000	Small tornado	One child injured; several small buildings destroyed and others unroofed. Considerable damage to telephone, electric wires, and poles.	Do.
Reno, Nev., and vicinity	27					High wind	Telephone poles were blown down and haystacks damaged in a few localities.	Do.
Hinds, Grenada, and Lee Counties, Miss.	27	12-1 a. m.		5	100,000	Probably tornadoes.	Several houses destroyed; poles and wires down. Heavy property damage in Grenada.	Official, U. S. Weather Bureau; Commercial Appeal (Memphis, Tenn.).
New York State and north Atlantic seaboard.	27, 28, 29			1		Rain, snow, wind, and sleet.	Hundreds of persons injured; buildings and signs damaged; transportation paralyzed. Several boats wrecked, the crews of 3 of which are missing.	Press (Binghamton, N. Y.); Star Gazette (Elmira, N. Y.); World; Times (New York).
Northeastern Ohio	27-28				350,000	Sleet, snow, and wind.	8 persons injured, traffic interrupted, trains delayed, and many trees and poles down. Greatest loss to the Ohio Telephone Co.	Official, U. S. Weather Bureau; Journal of Commerce (New York).
Southern New England coast.	28					do	Communication cut off at Block Island. No other damage reported.	Do.
Newport, Oreg.	30					High winds	Boat traffic tied up	Oregonian (Portland, Oreg.).

STORMS AND WEATHER WARNINGS.

WASHINGTON FORECAST DISTRICT.

Although very stormy weather prevailed much of the month along the steamer lanes between North America and Europe, the intense cyclonic areas charted over the north Atlantic Ocean did not become severe storms until after they had passed eastward from the New England coast, except on the 28th–29th, when a storm of exceptional severity prevailed along the coast north of Delaware Breakwater. Several stations reported maximum wind velocities of 60 miles an hour or more from the northeast, attended by thick weather with rain or snow, the highest velocity, 72 miles an hour occurring at Block Island, R. I., during the afternoon of the 28th. This storm developed during the 24th–25th over the central Rocky Mountain and Plateau regions, whence it moved slowly eastward with increasing intensity and was central over Arkansas on the morning of the 27th.

At this time a strong anticyclone was advancing eastward over Ontario and Quebec and a marked increase in pressure was in progress over New England and the Canadian Maritime Provinces. This distribution of pressure is always attended by stormy weather along the north Atlantic coast within 24 to 36 hours; therefore in the regular morning forecasts of the 27th was included the statement that there was a possibility of dangerous gales the following day along the coast from New Jersey northward. Northeast storm warnings were ordered displayed at 6 p. m. from Delaware Breakwater to Eastport, Me., and at 9:30 p. m. southeast warnings were displayed south of Delaware Breakwater to Cape Hatteras. The following morning the storm was central over Virginia and West Virginia with a strong pressure gradient to the northeastward and whole-gale warnings were ordered displayed at 9:30 a. m. from Block Island, R. I., to Provincetown, Mass. The storm center passed some distance south of Nantucket, Mass. (moving east-northeastward), the morning of the 29th, and all warnings were lowered by the morning of the 30th. Heavy snow fell over portions of New England and New York during the 28th–29th.

Storm warnings were displayed along portions of the middle Atlantic and north Atlantic coasts on a number of dates earlier in the month in connection with disturbances that moved eastward over the Lake region and the upper Ohio Valley, but no winds of 50 miles an hour, or over, were reported, except 52 miles from the northwest at New York, N. Y., on the 5th and 66 miles from the northwest at Block Island, R. I. on the 6th.

Cold-wave warnings were issued for portions of the Washington Forecast District on the 5th, 11th, 12th, 14th, 17th, and 18th, and these warnings, except that of the 14th, were verified over most of the areas for which they were issued.

Frost warnings were issued for portions of the South Atlantic or the East Gulf States on the following dates: 9th, 10th, 17th, 19th, 22d, 23d, 28th, 29th, and 31st; however, none were issued for southern Florida.—*Charles L. Mitchell.*

CHICAGO FORECAST DISTRICT.

Storm warnings.—The severe storm that reached the Lake region on the closing day of November moved rapidly eastward on December 1, and by night the center was over the mouth of the St. Lawrence River. At 3 p. m. of the 1st, northwest warnings were issued for the central and eastern portions of Lake Superior, but these, as well as the warnings that were continued on Lake Ontario on the night of the 1st, were lowered on the following morning. In both cases, however, the warnings were justified.

On the morning of the 4th a disturbance that developed two days previously over the State of Washington was central over northwestern Missouri, with increasing energy. Accordingly, southeast warnings were issued for southwestern Lake Michigan, except Chicago, and northeast warnings for the northwestern portion of the

Lake, and for Lake Superior from Duluth to Houghton. Later in the morning northeast warnings were extended over the remainder of Lake Superior and were also issued for Lake Huron and northeastern Lake Michigan, and for Chicago. Special observations at 2 p. m. indicated that the disturbance was moving more to the northward than at first expected; therefore, at 3:30 p. m., the northeast warnings on Lake Huron were changed to southeast, and at the same time southeast warnings were issued for Lake Erie; later, at 9:30 p. m., southeast warnings were extended over Lake Ontario. Verifying velocities from the directions indicated were confined to northern Lake Huron, but as the storm passed to the eastward practically all stations experienced verifying velocities from a westerly direction. Whitefish Point, Mich., reported a maximum velocity of 68 miles an hour, and Middle Island, one of 64 miles an hour. At 9 a. m. of the 5th the warnings were changed to northwest from Houghton east on Lake Superior, and also on northern Michigan, eastern Erie, Huron, and Ontario. Action had been taken one hour previously, however, by the officials at Alpena, Mich., and Buffalo, N. Y., to effect this change. Owing to the persistence of winds of gale force at Oswego, N. Y., on the morning of the 6th the warnings were continued over extreme eastern Ontario until 4 p. m. of that date.

Southeast warnings were issued on the night of the 6th for the west shore of Lake Michigan from Chicago to Sheboygan in anticipation of the development of a disturbance of wide extent then over the West, but the warning was lowered on the following morning when it had become apparent that winds of storm strength probably would not occur. However, as this disturbance reached the upper Lakes it increased in energy, and on the morning of the 8th northwest warnings were ordered for Lake Superior from Houghton eastward, and for Lake Huron and the eastern shore of Lake Michigan; while southwest warnings were displayed on Lake Ontario and on Lake Erie from Erie eastward. In most cases these warnings were verified. By 8 p. m. of the 8th the storm had spent its force on the Lakes and therefore all warnings were lowered.

On the evening of the 10th a disturbance of considerable geographic extent occupied the northern Rocky Mountain and Northern Plains States, while a high-pressure area of great magnitude covered the East. At that time northeast warnings were ordered for the Duluth and Ashland sections of Lake Superior, and southeast warnings for the remainder of that lake. On the following morning the disturbance extended from the upper Mississippi Valley southwestward to Colorado. An area of high pressure and low temperature appeared to the northwestward. Accordingly, the warnings on Lake Superior were changed to northwest and at the same time southwest warnings were issued for Lakes Michigan, Huron, Erie, and Ontario. As the result of special observations in the afternoon the warnings were changed to northwest on Lakes Michigan and Huron, and on Lake Superior from Marquette eastward, and on the following morning they were changed to northwest over eastern Lake Erie. All these warnings were fully verified, the storm being severe over certain portions of the lakes. At Buffalo, N. Y., a maximum velocity of 72 miles an hour was experienced; on Lake Superior the tug *Reliance* grounded on the rocky shores of Lizzard Island and was reported to have been wrecked.

The final storm warnings for the season were issued on the night of the 19th and the morning of the 20th in connection with a disturbance of moderate strength that was centered over the Red River at 8 p. m. of the 19th. Northwest warnings were issued at 10 p. m. for Lake Superior from Duluth to Houghton, and on the following morning these were extended over the remainder of the upper Lakes, except the west shore of Lake Michigan south of the Escanaba section. At the same time southwest warnings were displayed on the lower Lakes. The warnings were verified over extreme western Lake Superior and on the eastern shore of Lake Michigan, while elsewhere winds of near storm force occurred.

The only small-craft warning issued was that on the morning of the 7th by the Houghton official.

The storm-warning season closed on the 20th, and thereafter only one advisory warning was issued for Lake Michigan—that on the night of the 29th in connection with a disturbance that was advancing from the Plains States.

Cold-wave warnings.—Cold-wave warnings were issued for some portion of the district on eight different dates, but on only one date, namely the 11th, were warnings disseminated over a large portion of the district. On that date cold-wave warnings were issued for portions of the upper Mississippi and lower Missouri Valleys and Middle Plains States. and in the early afternoon the warnings were extended to the eastern and southern limits of the district. The fall in temperature occurred as expected, and on the morning of the 12th the line of zero temperature reached southward into southeastern Iowa.

Cold-wave warnings were also issued on the morning of the 14th for portions of the Plains States and in the afternoon the warnings were extended to include eastern Nebraska, western Iowa, and Missouri. These warnings were not fully verified, but nevertheless a marked fall in temperature occurred throughout the area for which the warnings had been issued.

Cold-wave conditions again developed on the morning of the 16th, when warnings were issued for southern and eastern Montana and for Wyoming, and in the afternoon for central Iowa. On the following morning lower Michigan, Indiana, and southern and eastern Illinois were included. All these warnings were verified, the temperature falling below zero on the morning of the 18th as far south as central Indiana.

A limited cold-wave warning was issued on the morning of the 19th for the extreme upper Missouri Valley, and the warning was verified in part.

The last cold-wave warning for the month was issued on the morning of the 20th and included in its scope upper Michigan and northern lower Michigan. This warning failed of verification owing to the rapid approach of an area of low pressure from the Northwest.

Stock warnings were issued during the month as follows: 6th and 11th, southeastern Wyoming; 13th, Wyoming, western South Dakota, and southern Montana; 14th, Kansas, Missouri, and Nebraska; 16th, Wyoming, Nebraska, and Kansas; 19th, North Dakota.—*C. A. Donnel.*

NEW ORLEANS FORECAST DISTRICT.

The movement of the areas of high pressure during this month was more eastward than southward and it is due largely to this fact that true cold waves occurred only in the northwestern portion of the district, although cold waves appeared at times to threaten the eastern and southern portions, also. The prevailing character of

pressure distribution was attended also by a comparative absence of stormy weather.

A moderate cold wave occurred on the 12th in the northwestern portion of the district, for which warnings had been issued the previous evening. Warnings were extended over nearly all portions of the remainder of the district on the morning of the 12th, but verifying temperatures did not occur.

Warnings were issued on the morning of the 14th for a cold wave in Oklahoma and the Texas Panhandle and were extended in the afternoon to include Arkansas and the northwestern portion of east Texas; but the cold wave occurred only as indicated in the warning issued in the morning.

On the morning of the 16th, cold-wave warnings were issued for the northern portion of west Texas. The cold wave occurred the following morning as forecast. Cold-wave warnings were extended at night on the 16th to include northwestern Arkansas, Oklahoma, and the northwestern portion of east Texas, and were further extended, on the morning of the 17th, to the coast, except the west coast of Texas. Cold weather extended farther south than in previous cold periods; but the change was gradual and was most felt in the southern portion of the district, on the morning of the 19th, when freezing temperature, or lower, occurred in the interior portions of Texas and Louisiana.

Warnings for stockmen were issued in connection with the cold waves.

Frost warnings for areas in the southern sections of the district were issued on the 15th, 18th, 19th, 20th, 21st, 22d, 27th, 28th, and 31st, and were generally verified.

Small-craft warnings were displayed on the Texas coast on the 12th and were justified. On the 26th Northwest storm warnings were ordered for the east coast of Texas and were verified.

Fire-weather warnings were issued for forested areas in western Oklahoma on the 19th and for areas in western Arkansas and southeastern Texas on the 26th—*R. A. Dyke.*

DENVER FORECAST DISTRICT.

The month was characterized by high temperature, and a deficiency in precipitation, except in the extreme northern portion of the district. North Pacific low-pressure areas were numerous, and a Plateau high-pressure area dominated weather conditions during the latter half of the month.

Warnings for a moderate cold wave were issued for eastern Colorado on the 4th. The southward movement of the HIGH was prevented, however, by another area of low pressure from the north Pacific which spread eastward over southern Wyoming. The temperature fell 10 to 18 degrees in eastern Colorado, but the warnings were verified only in extreme northeastern Colorado, although zero temperatures prevailed in parts of Montana and northeastern Wyoming.

Warnings for a moderate cold wave were issued for north-central Colorado on the 7th. During the following 24 hours the HIGH moved southward into the Plains States, dividing the disturbance, one portion remaining west of the mountains while the other moved rapidly northeastward to the Lake region. The warnings were verified only in the extreme north-central portion of Colorado. By the evening of the 10th pressure was rising along the Canadian border and the temperature ranged from 8 to 16 degrees below zero in the Canadian Northwest. Warning for a moderate cold wave was issued for eastern Colorado on the evening of the 10th, 36 hours in advance. On the morning of the 11th warnings for a moderate cold wave were issued for Utah, northern Arizona, northern and eastern New Mexico, and for a severe cold wave for eastern Colorado. The warnings for eastern Colorado and northern and eastern New Mexico were repeated on the evening of the 11th. The warnings were verified in eastern Colorado and east of the mountains in New Mexico, but failed on the western slope owing to the appearance of an area of low pressure on the California coast, which subsequently overspread the entire Southwest.

On the morning of the 14th warnings for a moderate cold wave were issued for Utah, northern Arizona, northern and eastern New Mexico, and Colorado. A portion of the LOW remained in the Southwest, however, and the warnings were verified only in the area east of the mountains in New Mexico. Warnings for a moderate cold wave were again issued for eastern Colorado and the district east of the mountains in New Mexico. On the evening of the 16th the warnings were verified in eastern New Mexico and in parts of eastern Colorado, temperatures of zero to 12 degrees above being reported in eastern Colorado. On the evening of the 30th livestock warnings were issued for Utah. Moderately heavy precipitation occurred in northern Utah on the 31st and a temperature of 16 degrees was reported at Modena 36 hours after the issue of the warnings. Frost warnings were issued on several dates for south-central Arizona and were generally fully verified.—*Frederick W. Brist.*

SAN FRANCISCO FORECAST DISTRICT.

Unusually stormy weather prevailed in the San Francisco Forecast District during the month of December, 1922. From the 1st until the 17th, a large high-pressure area extended almost continuously from northeastern Alaska southeastward to the Canadian Northwest. This apparently acted as a barrier to the passage of storms along the northern track and all but one or two entered the United States below the mouth of the Columbia River. As a result the rainfall in California was greater than usual. Beginning about the 19th, a high-pressure area formed over the Central Plateau States and conditions from then until near the end of the mouth were more nearly normal. Near the end of the month this high-pressure area disappeared and the barometer began rising over northeastern Alaska, which caused the storms from the ocean to again take the southern track.

Storm warnings were issued from one or more places on no less than 17 days. A few were not justified, judging from the velocity of the wind at our coast stations, but ships only a short distance from the coast experienced the full force of these gales. The most severe storm occurred near the end of the month at which time maximum velocities of 68 miles at Tatoosh Island, 76 at North Head and 49 at Eureka were reported.

Besides the storm warnings, frost was predicted at one or more places in California on 15 days. Cold-wave warnings were issued for southern Idaho and eastern Oregon on the 11th. The cold wave came as predicted and most of the frosts likewise occurred. The frosts, however, were not severe enough to do any material damage in the citrus orchards, though they brought the season to a close so far as grapes, tomatoes, etc., were concerned.—*E. A. Beals.*

RIVERS AND FLOODS.

By H. C. FRANKENFIELD, Meteorologist.

The heavy rains that fell in the South directly after the middle of the month were followed by moderate floods in the rivers of the Santee and Mobile systems, and there was also an equally moderate flood in the lower Apalachicola River of Florida. There were no other floods worthy of special mention. Warnings were issued whenever and wherever necessary and there were no losses except of lumber to the value of $3,000 in the Tombigbee system of Alabama. Here also the value of property saved by the warnings was $10,300.

Flood stages during December, 1922.

River.	Station.	Flood stage.	Above flood stages—dates.		Crest.	
			From—	To—	Stage.	Date.
ATLANTIC DRAINAGE.		*Feet.*			*Feet.*	
Santee	Rimini, S. C	12	21	26	13.6	25
	Do	12	31	(*)	12.0	31
	Ferguson, S. C	12	22	28	13.1	26
Saluda	Pelzer, S. C	7	18	18	7.5	18
Broad	Carlton, Ga	11	18	18	12.0	18
EAST GULF DRAINAGE.						
Apalachicola	Blountstown, Fla	15	21	24	16.2	22–23
Coosa	Lock No. 4, Lincoln, Ala.	17	18	20	17.5	18–19
Etowah	Canton, Ga	11	17	18	16.6	18
Tombigbee	Lock No. 4, Demopolis, Ala.	39	21	24	42.8	23
Black Warrior	Lock No. 10, Tuscaloosa, Ala.	46	18	19	51.5	18
MISSISSIPPI DRAINAGE.						
Tennessee	Knoxville, Tenn	12	18	18	12.4	18
PACIFIC DRAINAGE.						
Mokelumne	Bensons Ferry, Calif.	12	15	15	12.1	15
COLUMBIA BASIN.						
Santiam	Jefferson, Oreg	10	27	27	10.8	27

* Continued into January, 1923.

INFLUENCE OF WEATHER ON CROPS AND FARMING OPERATIONS, DECEMBER, 1922.

By J. WARREN SMITH, Meteorologist.

More than the normal amount of rain fell during December, from the Ohio Valley and Maryland southward and also in most far western and northwestern districts. The amounts, however, were considerably below normal in the Lake region and between the Mississippi Valley and the Rocky Mountains. The rainfall during the first half of the month in the Southeastern States was beneficial to winter-truck crops, but farm work was considerably interrupted, and at the same time the rather frequent rainfall in the Middle Atlantic Coast States materially replenished the water supply in that area. With the cessation of rains in southern Florida, the soil dried out rapidly and planting became active.

Severely cold weather with frequent, and in some places heavy, snows, prevailed in the Northwestern States during the weeks ending December 12 and 19, a condition which was generally unfavorable for stock and caused outdoor operations to be largely suspended. The snow drifted badly in parts of the northern Great Plains and traffic was impeded by snow in Montana and in some higher northern Rocky Mountain districts. There was some shrinkage of stock in Wyoming and heavy feeding was necessary in the northwestern grazing districts, but no material loss of stock was reported. The last 10 days of the month were unseasonably mild in the Northwestern States, with a rapid melting of snow, and the lower ranges were mostly free from snow cover in the central Rocky Mountain and north Pacific States at the close of the month.

The ground was generally bare of snow throughout the principal winter-wheat belt, and low temperatures prevailed during the middle portion of the month, but wheat was not materially damaged in any section. Substantial rains fell in most portions of the eastern half of the belt during the first two weeks of the month, which were beneficial for winter cereals and the increased moisture the latter part was very helpful in the Middle Atlantic Coast States. It continued dry, however, in the more western and southwestern portions of the winter-wheat belt where the crop was generally in poor condition, The soil was mostly in good condition to absorb the heavy snowfall in the more Northwestern States and substantial benefit resulted to wheat in that area; much wheat sown late in dry soil in eastern Washington germinated satisfactorily. The ample soil moisture in the South Atlantic and East Gulf States gave conditions satisfactory for winter grains in that area.

Citrus fruit matured slowly in Florida, owing to the prevailing warm weather, until the latter part of the month when the cooler weather favored more rapid development while, at the same time lower temperatures were favorable in Arizona. The weather was generally favorable for the development of oranges and lemons in California and navel oranges were ripening, and there was some picking the latter part of the month. There was some lack of moisture for strawberries in Florida but in general the crop made satisfactory progress.

CLIMATOLOGICAL TABLES.[1]

CONDENSED CLIMATOLOGICAL SUMMARY.

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation, by sections, December, 1922.

Section.	Temperature.								Precipitation.					
	Section average.	Departure from the normal.	Monthly extremes.						Section average.	Departure from the normal.	Greatest monthly.		Least monthly.	
			Station.	Highest.	Date.	Station.	Lowest.	Date.			Station.	Amount.	Station.	Amount.
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	54.4	+7.7	Selma	84	8	Florence	20	[2] 19	7.42	+2.30	Bay Minette	11.55	Goodwater	3.95
Alaska														
Arizona	46.7	+3.3	University of Arizona.	82	28	Spring Valley	-3	8	0.52	-0.61	Reno Ranger Station.	2.00	7 stations	0.00
Arkansas	47.8	+5.7	Dutton	86	5	Marked Tree	12	18	4.59	+0.50	El Dorado	8.28	Whitecliffs	1.00
California	47.7	+1.2	Indio	84	20	Madeline	-10	8	7.33	+3.36	Deer Creek	21.65	3 stations	0.00
Colorado	28.0	+3.5	Canon City	75	29	Fraser	-36	18	1.26	+0.21	Crested Butte	7.42	2 stations	0.00
Florida	64.6	+5.3	Fort Pierce	91	8	2 stations	29	22	2.90	-0.07	Bluff Springs	12.19	Ritta	0.35
Georgia	53.8	+6.7	2 stations	89	[2] 5	Clayton	22	[2] 29	5.58	+1.35	Clayton	12.40	St. George	2.03
Hawaii	70.8	+0.9	Waiawa	90	20	Volcano Observatory	46	14	1.62	-7.24	Luakaha (upper)	8.99	11 stations	0.00
Idaho	24.1	-2.1	2 stations	60	[2] 6	New Meadows	-28	12	2.82	+0.99	Sandpoint	8.06	Wendell	0.33
Illinois	32.1	+1.9	Harrisburg	70	1	Rockford	-16	18	2.62	+0.48	McLeansboro	7.02	Quincy	0.51
Indiana	33.3	+1.4	3 stations	69	[2] 1	Collegeville	-19	18	4.22	+1.48	Huntingburg	10.17	Whiting	1.28
Iowa	24.0	+0.1	Thurman	65	29	3 stations	-25	18	0.37	-0.85	Wescott	0.97	3 stations	T.
Kansas	34.4	+3.2	Medicine Lodge	75	29	2 stations	-5	[2] 17	0.07	-0.85	Columbus	1.17	11 stations	0.00
Kentucky	41.5	+4.4	Williamsburg	77	8	Williamstown	5	19	5.64	+1.70	Middlesboro	9.30	Cloverport	3.79
Louisiana	59.7	+8.2	Melville	87	1	Plain Dealing	22	[2] 19	6.68	+1.79	Lafayette	12.82	Robeline	1.40
Maryland-Delaware	36.3	+1.7	Cumberland	71	8	Grantsville	3	19	3.84	+0.44	Public Landing	7.72	Chewsville	2.32
Michigan	23.7	-1.3	Hastings	61	1	Humboldt	-36	19	1.48	-0.56	Grand Marais	5.57	Sandusky	0.41
Minnesota	12.6	-2.1	Taylors Falls	60	1	Roseau	-35	19	0.67	-0.21	Norden	3.10	Taylors Falls	T.
Mississippi	54.9	+7.7	2 stations	85	[2] 4	4 stations	20	19	7.07	+1.80	Edinburg	11.93	Fruitland Park	3.19
Missouri	36.3	+2.9	Hollister (3)	75	7	Downing	-6	18	2.11	-0.14	Doniphan	5.25	Grant City	0.00
Montana	16.6	-6.6	2 stations	60	[2] 23	Fortine	-46	14	1.35	+0.39	Heron	8.10	Conrad	0.10
Nebraska	26.4	+0.5	Curtis	68	24	Gordon	-31	17	0.16	-0.56	Merriman	1.17	16 stations	0.00
Nevada	34.5	+3.1	Las Vegas	79	[2] 22	San Jacinto	-12	17	1.30	+0.49	Reno	3.03	Mina	0.00
New England	23.4	-2.1	Springfield, Mass.	74	[2] 3	Woodland, Me.	-36	20	2.86	-0.45	Nantucket, Mass.	4.87	Cornwall, Vt.	0.99
New Jersey	32.5	-0.4	Tuckerton	65	1	Sussex	-8	30	3.86	-0.11	Pleasantville	5.26	Newton	3.09
New Mexico	38.3	+4.5	Hobbs	84	9	Red River Canyon	-7	31	0.27	-0.45	Diener	4.95	48 stations	0.00
New York	26.8	+0.6	Dansville	66	8	Indian Lake	-27	30	2.69	-0.32	Greenfield Center	5.31	Ogdensburg	0.51
North Carolina	46.5	+4.9	Smithfield	78	[2] 5	Jefferson	12	20	5.07	+1.05	Rock House	12.03	Durham	2.86
North Dakota	8.5	-4.5	Energy	55	27	2 stations	-34	11	0.57	+0.13	Walhalla	2.43	Wahpeton	0.00
Ohio	32.5	+1.6	2 stations	72	[2] 8	4 stations	-13	[2] 16	3.29	+0.48	Dam No. 28	6.34	Amesville	1.42
Oklahoma	44.2	+4.8	Walters	84	8	2 stations	2	18	0.78	-0.83	Watts	5.08	4 stations	0.00
Oregon	29.3	-1.9	Bend	69	4	Ukiah	-27	14	6.31	+2.03	Jewell	20.46	Andrews	0.98
Pennsylvania	31.5	+0.8	2 stations	69	8	Hawley	-9	30	2.75	-0.56	Confluence	4.55	Center Hall	1.19
Porto Rico														
South Carolina	51.0	+4.6	Summerville	86	2	Anderson	22	20	4.90	+1.50	Liberty	9.81	Columbia	2.61
South Dakota	17.5	-3.4	2 stations	60	28	Kennebec	-34	17	0.53	-0.11	Deadwood	1.90	Jefferson	T.
Tennessee	46.1	+6.2	do	77	8	4 stations	14	19	7.68	+3.12	Tullahoma	12.17	New River	4.42
Texas	54.6	+5.1	Rossville	93	1	Romero	2	18	0.59	-1.57	Alvin	9.93	34 stations	0.00
Utah	30.8	+4.2	Farmington	71	14	Pine View	-14	21	1.95	+0.83	Silver Lake	9.96	Salduro	0.07
Virginia	41.0	+3.8	Woodstock	77	2	Mount Weather	7	19	4.04	+0.55	Mendota	8.28	Callaville	2.39
Washington	27.9	-5.5	Kiona	69	24	Deer Park	-32	12	6.09	+1.19	Paradise Inn	28.90	Sunnyside	0.71
West Virginia	36.6	+3.2	2 stations	75	8	Cheat Bridge	2	30	4.71	+1.23	Kayford	7.27	Wardensville	1.03
Wisconsin	18.6	-1.5	Beloit	64	2	Long Lake	-35	19	0.75	-0.56	Plum Island	1.67	Danbury	0.10
Wyoming	20.8	-0.5	2 stations	61	24	Spencer	-34	15	0.91	+0.18	Foxpark	3.21	Pavillion	0.00

[1] For description of tables and charts, see REVIEW, July, 1922, pp. 384-385.

[2] Other dates also.

TABLE 1.—*Climatological data for Weather Bureau stations, December, 1922.*

Districts and stations.	Elevation of instruments: Barometer above sea level.	Elevation of instruments: Thermometer above ground.	Elevation of instruments: Anemometer above ground.	Pressure: Station, reduced to mean of 24 hours.	Pressure: Sea level, reduced to mean of 24 hours.	Pressure: Departure from normal.	Temperature of the air: Mean max.+mean min.÷2.	Temperature of the air: Departure from normal.	Temperature of the air: Maximum.	Temperature of the air: Date.	Temperature of the air: Mean maximum.	Temperature of the air: Minimum.	Temperature of the air: Date.	Temperature of the air: Mean minimum.	Temperature of the air: Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity.	Precipitation: Total.	Precipitation: Departure from normal.	Precipitation: Days with 0.01 inch, or more.	Wind: Total movement.	Wind: Prevailing direction.	Wind: Maximum velocity: Miles per hour.	Wind: Maximum velocity: Direction.	Wind: Maximum velocity: Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet, and ice on ground at end of month.
	Ft.	Ft.	Ft.	In.	In.	In.	° F.	° F.	° F		° F	° F.		° F	° F.	° F.	° F.	%	In.	In.		Miles.								0-10	In.	In.
New England.							27.3	−2.0										77	3.11	−0.3										7.2		
Eastport	76	67	85	29.99	30.08	+.10	22.4	−3.9	46	12	30	−8	20	14	34	20	15	76	3.26	−0.7	16	10,451	w.	58	ne.	28	5	7	19	7.5	27.9	15.8
Greenville, Me.	1,070	6	......	28.89	30.10	......	15.1	......	48	2	24	−19	20	6	36	......	......	......	2.79	......	15	......	......	......	......	......	9	3	19	......	27.4	25.0
Portland, Me.	103	82	117	30.01	30.14	+.11	23.8	−3.8	53	1	31	−3	20	17	25	21	16	73	4.81	+1.1	15	7,016	n.	38	n.	28	6	6	19	7.0	32.8	24.6
Concord	288	70	79	29.81	30.14	+.08	22.9	−3.5	59	1	32	−13	20	14	38	......	......	......	1.73	−1.6	12	3,593	nw.	32	w.	1	8	6	17	6.5	19.5	12.7
Burlington	404	11	48	29.66	30.13	+.08	22.0	−0.5	56	1	30	−11	30	14	34	......	......	......	1.17	−0.5	10	10,991	s.	54	s.	31	5	7	19	7.6	13.4	5.0
Northfield	876	12	60	29.14	30.14	+.09	18.6	−1.9	55	1	29	−24	30	8	40	17	14	84	1.85	−0.9	12	5,936	s.	37	sw.	1	4	5	22	8.0	25.5	16.5
Boston	125	115	188	29.98	30.12	+.07	30.9	−1.8	61	1	37	8	20	24	24	28	23	74	3.01	−0.4	9	7,852	w.	35	w.	2	7	6	18	7.3	14.7	4.0
Nantucket	12	14	90	30.08	30.09	+.04	35.6	−1.1	53	1	41	19	20	30	20	33	29	82	4.87	+1.2	11	12,152	w.	53	n.	29	5	6	20	7.5	6.3	0.0
Block Island	26	11	46	30.08	30.11	+.05	34.2	−1.8	54	1	40	16	7	28	25	32	28	79	2.67	−1.2	11	15,169	nw.	72	ne.	29	7	6	18	6.9	3.7	T.
Providence	160	215	251	29.94	30.12	+.06	30.0	−1.6	55	1	36	7	20	23	27	27	22	75	2.58	−1.3	12	9,146	nw.	61	nw.	6	7	7	17	6.6	10.9	1.0
Hartford	159	122	140	29.96	30.14	+.07	29.0	−0.8	56	2	36	5	20	22	29	26	21	76	4.52	+1.0	12	5,243	nw.	39	nw.	6	5	6	20	7.5	12.1	6.0
New Haven	106	74	153	30.02	30.14	+.07	31.0	−1.5	53	2	37	12	30	25	26	28	23	75	3.70	0.0	13	6,586	ne.	48	ne.	28	8	6	17	6.5	6.2	3.0
Middle Atlantic States.							36.6	+1.1										76	3.21	0.0										7.0		
Albany	97	102	115	30.04	30.15	+.07	27.8	−0.7	60	1	35	0	30	20	32	25	21	77	2.10	−0.5	9	6,222	s.	35	s.	31	10	5	16	6.3	17.1	4.5
Binghamton	871	10	84	29.15	30.11	+.02	28.3	+0.6	58	1	36	0	19	20	30	......	......	......	2.13	−0.3	12	4,723	nw.	25	nw.	5	5	8	18	7.3	9.9	1.0
New York	314	414	454	29.79	30.15	+.06	34.3	−0.7	56	1	40	13	30	28	20	31	25	71	3.29	−0.2	12	11,408	nw.	63	ne.	28	5	10	16	7.3	6.0	0.8
Harrisburg	374	94	104	29.76	30.18	+.06	32.9	+0.1	59	1	40	13	19	26	22	29	25	75	2.41	−0.2	14	4,280	nw.	27	n.	29	6	9	16	6.6	7.1	T.
Philadelphia	117	123	190	30.03	30.16	+.05	36.1	+0.4	57	1	42	16	19	30	24	33	27	71	3.29	+0.2	14	7,026	ne.	36	ne.	28	4	7	20	7.5	2.2	T.
Reading	325	81	98	29.79	30.16	......	33.0	......	54	1	39	12	19	27	20	30	26	77	3.18	−0.1	13	4,155	nw.	29	e.	28	5	12	14	6.9	6.1	0.0
Scranton	805	111	119	29.26	30.15	+.05	30.8	+1.0	55	1	38	7	19	24	23	28	25	79	2.31	−0.3	13	5,320	s.	34	sw.	5	3	13	15	7.0	9.3	0.1
Atlantic City	52	37	172	30.06	30.14	+.04	37.4	+1.0	58	1	44	16	30	31	26	35	31	79	4.79	+1.0	12	11,452	nw.	60	ne.	28	4	5	22	7.6	5.0	T.
Cape May	18	13	49	30.15	30.17	+.06	38.3	+0.3	57	1	45	18	20	32	25	36	33	82	4.13	+0.4	12	4,725	nw.	30	nw.	12	5	9	17	7.1	0.8	0.0
Sandy Hook	22	10	55	30.12	30.14	......	34.4	......	54	1	39	18	19	30	19	32	27	76	3.39	......	14	10,981	ne.	50	ne.	28	5	11	15	6.9	4.2	0.0
Trenton	190	159	183	29.93	30.15	......	32.9	......	56	1	40	14	30	26	24	30	26	77	3.46	+0.3	15	7,695	ne.	42	ne.	28	3	10	18	7.4	7.5	2.0
Baltimore	123	100	113	30.03	30.16	+.03	37.4	+0.2	61	1	44	16	19	31	21	33	28	73	3.43	+0.4	12	3,953	n.	24	ne.	28	5	8	18	6.9	2.5	0.0
Washington	112	62	85	30.03	30.16	+.03	37.6	+1.0	64	1	45	17	20	30	26	33	28	71	3.48	+0.3	13	4,354	n.	28	nw.	5	5	9	17	7.0	1.7	0.0
Lynchburg	681	153	188	29.39	30.15	+.03	42.5	+3.0	72	8	52	16	20	33	41	36	32	73	3.42	+0.2	13	4,536	w.	36	nw.	29	5	10	16	7.0	T.	0.0
Norfolk	91	170	205	30.05	30.15	+.02	46.6	+3.6	68	1	54	26	19	39	25	42	39	81	2.93	−0.6	16	9,518	ne.	42	sw.	1	5	8	18	7.2	1.5	0.0
Richmond	* 144	11	52	30.00	30.16	+.02	42.2	+1.2	72	1	51	20	20	33	34	37	33	78	3.14	+0.1	14	5,363	ne.	27	nw.	29	7	7	17	6.8	0.2	0.0
Wytheville	2,304	49	55	27.70	30.14	−.01	39.8	+4.5	62	26	48	18	20	31	31	36	32	80	3.85	+0.1	15	4,865	w.	28	w.	23	10	3	18	6.7	T.	0.0
South Atlantic States.							52.4	+4.8										83	3.95	+0.6										6.8		
Asheville	2,255	70	84	27.75	30.16	.00	44.6	+6.8	71	8	54	23	20	36	38	40	36	77	4.93	+1.8	15	6,264	se.	37	nw.	28	8	6	17	6.9	0.1	0.0
Charlotte	779	55	62	29.30	30.15	−.01	46.6	+3.6	72	9	54	24	20	39	31	42	39	80	4.47	+0.6	17	3,991	sw.	19	sw.	28	7	3	21	7.2	0.0	0.0
Hatteras	11	12	11	30.11	30.12	−.01	52.0	+1.9	66	8	58	36	19	46	19	49	47	88	6.06	+1.0	16	10,671	sw.	52	nw.	22	6	9	16	6.5	0.0	0.0
Manteo	12	5	42	......	......	......	48.6	......	73	8	58	29	24	39	36	......	......	......	3.80	......	6	......	sw.	......	......	......	17	1	13	......	T.	0.0
Raleigh	376	103	110	29.74	30.16	+.01	46.3	+3.6	72	3	54	23	20	38	28	43	41	86	3.47	+0.3	17	5,917	sw.	40	w.	1	7	4	20	7.3	0.6	0.0
Wilmington	78	81	91	30.07	30.15	+.01	53.2	+6.0	76	5	62	30	30	45	28	48	46	85	3.81	+0.7	17	5,910	sw.	24	se.	31	9	6	16	6.3	0.0	0.0
Charleston	48	11	92	30.09	30.14	−.01	56.3	+4.6	79	3	64	34	20	49	23	51	49	86	4.61	+1.5	15	8,411	sw.	34	n.	20	8	5	18	6.5	0.0	0.0
Columbia, S. C.	351	41	57	29.77	30.16	.00	52.0	+4.8	76	3	60	29	20	44	29	47	43	79	2.61	−0.3	14	5,132	ne.	27	sw.	28	6	6	19	7.2	0.0	0.0
Due West	711	10	55	29.39	30.18	......	48.6	......	73	3	57	28	20	40	34	......	......	......	4.25	......	15	6,286	sw.	38	w.	15	7	0	24	7.3	0.0	0.0
Greenville, S. C.	1,039	113	122	29.02	30.13	......	47.8	......	68	8	55	27	20	41	27	44	40	82	6.80	......	18	6,377	ne.	32	sw.	28	7	7	17	6.9	T.	0.0
Augusta	180	62	77	29.95	30.14	−.02	53.9	+5.7	77	3	63	32	20	45	31	49	46	83	3.36	−0.1	12	4,004	e.	26	w.	28	6	6	19	7.1	0.0	0.0
Savannah	65	150	194	30.08	30.15	.00	57.2	+5.9	79	3	65	36	20	50	23	52	49	81	3.65	+0.6	14	8,801	sw.	42	w.	28	8	5	18	6.6	0.0	0.0
Jacksonville	43	209	245	30.10	30.14	.00	61.6	+5.3	80	8	69	38	21	54	21	56	54	86	2.54	−0.4	9	8,718	sw.	41	s.	31	11	7	13	5.9	0.0	0.0
Florida Peninsula.							70.6	+4.1										79	2.59	+0.6										3.9		
Key West	22	10	64	30.08	30.10	+.02	73.6	+3.3	84	19	78	57	30	69	17	68	66	82	3.02	+1.2	9	7,889	ne.	32	w.	20	20	9	2	3.2	0.0	0.0
Miami	25	71	79	30.11	30.14	......	71.8	+3.8	82	20	77	52	23	67	20	66	63	77	1.19	−1.0	7	5,682	e.	25	e.	31	17	10	4	3.7	0.0	0.0
Sand Key	23	39	72	30.09	30.12	+.04	73.2	......	83	19	76	61	30	71	12	68	66	77	2.34	......	9	12,143	ne.	39	sw.	16	20	9	2	3.4	0.0	0.0
Tampa	35	79	92	30.16	30.14	+.02	66.3	+5.1	81	16	74	44	23	59	25	60	58	81	3.57	+1.6	5	3,878	e.	25	w.	28	11	12	8	5.2	0.0	0.0
East Gulf States.							56.5	+7.0										86	6.80	+2.3										6.7		
Atlanta	1,174	190	216	28.88	30.13	−.03	50.6	+5.9	73	2	58	30	21	44	24	48	46	88	6.20	+1.7	16	9,536	w.	46	nw.	28	6	2	23	7.5	0.0	0.0
Macon	370	78	87	29.76	30.16	.00	54.0	+7.2	76	4	62	32	20	45	30	50	48	85	5.48	+1.1	13	4,658	sw.	24	nw.	31	5	4	22	7.4	0.0	0.0
Thomasville	273	49	58	29.84	30.14	−.01	59.5	+7.0	78	5	68	35	29	51	31	54	52	89	6.33	+2.6	14	3,493	sw.	17	w.	28	6	7	18	7.1	0.0	0.0
Apalachicola	36	42	49	30.09	30.13	......	60.9	......	78	17	67	39	29	55	20	58	56	90	4.98	......	10	5,688	s.	33	ne.	20	7	11	13	6.2	0.0	0.0
Pensacola	56	149	185	30.06	30.12	−.03	60.4	+6.4	74	5	66	36	29	54	27	58	57	91	6.02	+1.8	12	9,482	s.	46	s.	27	8	7	16	6.3	0.0	0.0
Anniston	741	9	57	29.34	30.15	−.01	52.2	+8.0	78	8	60	28	13	44	31	......	......	......	7.05	+2.5	14	4,967	se.	26	se.	31	7	4	20	7.1	0.0	0.0
Birmingham	700	11	48	29.37	30.15	−.01	53.2	+5.9	77	8	61	28	19	45	31	49	46	80	7.63	+3.0	14	6,264	s.	38	se.	31	7	3	21	7.1	0.0	0.0
Mobile	57	125	161	30.05	30.11	−.04	60.1	+7.2	79	8	67	37	29	53	25	57	55	89	9.10	+4.5	11	7,253	s.	31	s.	26	4	17	10	6.3	0.0	0.0
Montgomery	223	100	112	29.89	30.14	−.02	56.2	+6.8	79	1	64	33	29	48	28	52	49	82	6.82	+2.3	11	5,215	sw.	24	nw.	17	8	5	18	6.6	0.0	0.0
Corinth	469	6	......	......	......	......	49.9	......	78	8	60	22	19	40	35	......	......	......	7.23	......	14	......	n.	......	......	......	7	10	14	......	0.0	0.0
Meridian	375	85	93	29.71	30.12	−.04	55.6	+8.7	80	8	65	29	29	46	29	51	49	84	5.73	+0.5	15	4,840	sw.	32	sw.	8	6	10	15	6.5	0.0	0.0
Vicksburg	247	65	73	29.85	30.13	−.02	55.7	+5.7	78	4	64	26	19	47	26	51	49	86	7.40	+2.4	14	5,766	ne.	25	sw.	26	9	3	19	6.5	0.0	0.0
New Orleans	53	76	84	30.05	30.11	−.02	63.5	+7.9	82	2	71	43	29	56	23	59	57	86	7.01	+2.6	10	4,703	s.	22	nw.	15	9	12	10	5.6	0.0	0.0
West Gulf States.							54.9	+5.9										77	1.40	−1.5										5.3		
Shreveport	249	77	93	29.82	30.10	−.03	54.8	+5.9	83	8	64	26	19	46	32	50	47	81	2.59	−1.8	10	5,782	s.	31	w.	27	11	5	15	5.9	0.0	0.0
Bentonville	1,303	11	44	......	......	......	43.0	+5.5	73	7	53	17	12	32	37	......	......	......	2.71	......	8	......	......	......	......	......	11	6	14	......	0.0	0.0
Fort Smith	457	79	94	29.58	30.07	−.06	46.6	+4.9	77	7	56	25	19	38	32	40	35	70	3.27	+0.4	9	6,424	e.	34	nw.	27	9	10	12	5.9	0.0	0.0
Little Rock	357	136	144	29.70	30.09	−.05	48.4	+4.9	74	2	57	22	19	40	31	44	41	80	3.38	−0.9	11	6,639	s.	29	n.	12	9	8	14	6.1	0.0	0.0
Brownsville	57	4	26	29.99	30.05	......	67.4	......	87	9	76	41	18	59	33	61	58	82	0.38	......	6	6,217	s.	30	sw.	30	13	13	5	4.2	0.0	0.0
Corpus Christi	20	11	73	30.06	30.08	−.04	63.1	+6.5	83	30	71	38	19	55	28	58	54	80	0.01	−1.3	1	8,303	s.	40	n.	17	9	9	13	5.5	0.0	0.0
Dallas	512	109	117	29.53	30.09	......	52.8	......	81	7	63	23	19	42	35	......	......	......	0.37	......	8	6,686	s.	47	nw.	27	11	10	10	5.1	0.0	0.0
Fort Worth	670	106	114	29.34	30.06	−.06	52.8	+5.3	83	7	63	28	10	42	38	45	39	64	0.06	−1.2	3	6,656	s.	39	w.	27	14	6	11	4.8	T.	0.0
Galveston	54	106	114	30.04	30.10	−.02	62.4	+6.0	76	5	68	39	19	57	20	59	58	88	2.56	−1.2	9	7,892	se	31	nw.	27	10	12	9	5.5	0.0	0.0
Groesbeck	461	11	56	29.58	30.07	......	55.0	......	81	1	66	25	20	44	37	......	......	......	0.26	......	4	8,219	s.	35	nw.	27	10	11	10	5.3	0.0	0.0
Houston	138	111	121	29.93	30.08	......	61.4	+6.9	83	2	70	35	19	53	29	......	......	......	2.97	......	10	5,557	s.	31	se.	30	11	7	13	5.4	0.0	0.0
Palestine	510	64	72	29.55	30.08	−.04	56.2	+6.8	82	8	65	28	19	47	31	49	44	71	0.46	−3.2	9	6,183	sw.	30	nw.	27	7	10	14	6.2	0.0	0.0
Port Arthur	34	58	66	30.04	30.08	......	61.1	......	79	8	69	34	19	54	25	57	55	87	6.98	......	11	6,679	s.	36	sw.	26	10	8	13	5.7	0.0	0.0
San Antonio	701	119	132	29.34	30.08	−.03	59.6	+6.5	82	4	69	31	19	50	34	52	45	67	0.10	−1.5	2	5,561	s.	40	nw.	26	14	10	7	4.3	0.0	0.0
Taylor	582	55	63	29.48	30.10	−.01	55.8	+5.2	80	1	66	28	19	45	34	......	......	......	0.14	−2.5	2	6,598	s.	28	nw.	26	9	10	12	5.5	0.0	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, December, 1922*—Continued.

Districts and stations.	Elevation of instruments. Barometer above sea level.	Elevation of instruments. Thermometer above ground.	Elevation of instruments. Anemometer above ground.	Pressure. Station, reduced to mean of 24 hours.	Pressure. Sea level, reduced to mean of 24 hours.	Pressure. Departure from normal.	Temperature of the air. Mean max.+mean min.÷2.	Temperature of the air. Departure from normal.	Temperature of the air. Maximum.	Temperature of the air. Date.	Temperature of the air. Mean maximum.	Temperature of the air. Minimum.	Temperature of the air. Date.	Temperature of the air. Mean minimum.	Temperature of the air. Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity.	Precipitation. Total.	Precipitation. Departure from normal.	Precipitation. Days with 0.01 inch, or more.	Wind. Total movement.	Wind. Prevailing direction.	Wind. Maximum velocity. Miles per hour.	Wind. Maximum velocity. Direction.	Wind. Maximum velocity. Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet, and ice on ground at end of month.
	Ft.	Ft.	Ft.	In.	In.	In.	° F.	° F.	° F.		° F.	° F.		° F.	° F.	° F.	° F.	%	In.	In.		Miles.								0-10	In.	In.
Ohio Valley and Tennessee.							**39.5**	**+3.0**										**77**	**4.98**	**+1.6**										**6.8**		
Chattanooga	762	189	213	29.32	30.14	−.02	49.4	+6.1	74	8	57	27	19	42	31	44	40	74	8.95	+4.6	15	6,540	sw.	39	w.	15	8	5	18	6.6	0.0	0.0
Knoxville	996	102	111	29.06	30.13	−.03	46.6	+6.9	72	8	55	25	19	38	30	42	39	78	7.27	+3.1	16	4,595	sw.	29	sw.	15	7	5	19	7.1	0.0	0.0
Memphis	399	76	97	29.67	30.11	−.04	48.4	+4.8	73	8	56	20	19	40	31	43	48	72	5.19	+0.8	14	7,079	s.	32	sw.	4	8	3	20	7.0	0.0	0.0
Nashville	546	168	191	29.54	30.14	−.01	46.0	+5.0	74	8	55	18	19	37	31	42	38	76	6.29	+2.5	18	8,102	ne.	45	se.	31	7	7	17	6.5	T.	0.0
Lexington	989	193	230	29.05	30.15	+.01	39.1	+2.8	68	8	48	11	19	31	31	....	....	....	5.67	+2.4	15	11,112	sw.	60	s.	31	8	8	15	6.6	0.1	0.0
Louisville	525	219	255	29.55	30.14	.00	39.2	+1.6	68	8	48	11	18	31	33	36	30	71	4.96	+1.2	13	8,783	s.	39	s.	11	8	6	17	6.6	0.2	0.0
Evansville	431	139	175	29.65	30.13	.00	39.4	+3.0	66	1	48	12	18	31	31	36	31	74	5.94	+2.1	13	8,899	n.	37	s.	30	6	10	15	6.6	0.4	0.0
Indianapolis	822	194	230	29.22	30.13	+.01	33.4	+0.8	63	8	41	−1	18	26	35	31	27	78	4.45	+1.4	11	9,409	s.	38	ne.	27	7	4	20	7.0	2.6	0.0
Royal Center	736	11	55	29.29	30.12	......	28.2	......	61	8	37	−12	18	19	37	....	....	....	2.40	......	8	8,244	w.	32	w.	12	6	6	19	7.0	8.5	0.0
Terre Haute	575	96	129	29.49	30.12	......	34.2	......	63	4	42	−4	18	26	36	31	28	80	5.22	......	10	7,545	s.	36	n.	28	4	11	16	7.0	1.6	0.0
Cincinnati	628	11	51	29.44	30.14	+.01	35.2	+1.8	66	8	44	6	19	27	34	....	30	80	4.00	+1.1	10	5,902	sw.	28	ne.	28	6	9	16	6.9	1.3	0.0
Columbus	824	179	222	29.23	30.13	+.01	33.6	+1.2	64	8	41	4	18	26	33	31	27	80	2.69	−0.1	11	8,613	s.	41	n.	28	6	7	18	6.8	2.1	0.0
Dayton	899	181	216	29.14	30.13	......	34.3	+1.2	62	8	42	1	18	26	32	31	28	81	3.62	+1.0	10	8,292	sw.	42	ne.	28	9	7	15	6.5	4.0	0.0
Elkins	1,947	50	67	28.04	30.17	+.05	35.4	+2.9	67	8	47	8	30	24	36	32	28	81	4.53	+1.1	15	4,101	w.	29	nw.	5	6	6	19	7.1	4.5	0.0
Parkersburg	638	77	84	29.48	30.16	+.02	37.4	+2.2	71	8	47	12	19	28	31	33	28	74	4.13	+1.4	16	3,897	se.	33	w.	5	7	6	18	7.0	3.0	0.0
Pittsburgh	842	353	410	29.20	30.14	+.03	35.6	+1.4	64	8	44	9	19	28	31	32	28	74	1.98	−0.8	12	8,144	sw.	44	nw.	5	5	5	21	7.3	2.1	0.0
Lower Lake Region.							**28.9**	**−0.2**										**76**	**2.57**	**−0.3**										**7.3**		
Buffalo	767	247	280	29.24	30.10	+.04	28.9	−0.9	54	8	35	5	18	23	30	27	24	79	3.23	−0.1	16	14,999	w.	70	w.	12	4	8	19	7.5	16.6	4.0
Canton	448	10	61	29.58	30.08	......	21.4	−1.3	55	1	29	−11	30	14	38	....	....	....	1.03	−2.6	13	9,689	sw.	53	w.	12	7	3	21	7.2	9.1	0.6
Oswego	335	76	91	......	30.11	+.05	27.8	−1.2	58	1	34	0	30	21	26	....	....	....	2.18	−1.4	18	10,211	s.	42	nw.	6	2	7	22	....	38.2	5.5
Rochester	523	86	102	29.52	30.12	+.06	29.2	−0.1	62	8	36	5	19	23	36	26	20	71	3.01	+0.1	13	7,586	w.	42	w.	12	4	5	22	8.0	24.2	11.0
Syracuse	597	97	113	29.45	30.12	+.05	28.2	−0.1	59	1	35	2	30	22	32	....	....	....	2.84	+0.2	12	10,219	s.	46	s.	5	5	7	19	7.4	16.1	2.0
Erie	714	130	166	29.31	30.10	+.03	31.2	−0.5	64	8	38	13	18	25	30	29	24	72	2.25	−0.8	12	12,442	sw.	53	se.	4	1	4	26	8.7	14.6	T.
Cleveland	762	190	201	29.27	30.12	+.03	31.8	+0.6	63	8	38	8	19	25	32	29	24	74	2.45	−0.1	13	11,208	s.	50	ne.	28	3	10	18	7.5	13.1	T.
Sandusky	629	62	103	29.40	30.10	+.01	30.7	−0.4	62	8	37	5	19	24	33	....	....	....	3.07	+0.7	8	9,738	sw.	42	nw.	12	3	12	16	6.8	12.6	0.0
Toledo	628	208	243	29.42	30.12	+.04	30.0	−0.4	61	1	37	4	16	23	34	27	23	78	3.31	+1.0	9	10,846	sw.	48	sw.	1	11	3	17	6.1	9.7	T.
Fort Wayne	856	113	124	29.17	30.12	......	29.8	+2.5	60	8	37	−4	18	22	35	26	23	78	3.12	......	11	7,502	sw.	30	w.	12	6	7	18	6.9	8.5	0.0
Detroit	730	218	258	29.29	30.11	+.04	29.2	−0.1	60	1	36	4	18	22	33	27	23	81	2.31	−0.1	13	9,185	w.	46	w.	1	7	9	15	6.8	14.2	T.
Upper Lake Region.							**22.6**	**−1.8**										**81**	**1.27**	**−0.8**										**7.4**		
Alpena	609	13	92	29.37	30.06	+.04	24.2	−0.6	58	1	30	−1	19	18	29	22	18	81	0.91	−1.3	18	9,996	w.	48	w.	5	0	15	16	7.5	13.8	0.5
Escanaba	612	54	60	29.36	30.06	+.03	17.8	−3.8	45	1	26	−11	18	10	31	16	13	83	0.94	−0.8	10	7,632	w.	32	nw.	5	9	7	15	6.3	7.0	1.0
Grand Haven	632	54	89	29.38	30.09	+.04	28.0	−2.1	52	1	34	8	18	22	24	26	23	83	1.50	−1.0	12	11,014	w.	52	w.	5	3	2	26	8.5	9.0	0.0
Grand Rapids	707	70	87	29.30	30.10	+.05	27.7	−1.1	59	1	34	6	18	22	29	25	21	78	1.40	−1.1	13	5,385	w.	28	w.	12	3	7	21	8.0	7.4	T.
Houghton	684	62	99	29.24	30.00	−.02	18.4	−2.5	42	25	25	−15	19	12	27	....	....	....	2.59	+0.1	19	8,868	w.	58	w.	5	0	3	28	9.6	27.3	13.5
Lansing	878	11	62	29.11	30.08	......	26.1	−0.7	57	1	34	2	18	19	34	24	21	85	1.03	−1.0	10	5,499	w.	24	w.	12	4	6	21	7.5	4.3	0.0
Ludington	637	60	66	29.35	30.07	......	25.8	......	50	1	32	4	18	20	22	24	21	82	1.07	......	12	10,096	w.	46	w.	4	2	8	21	7.9	8.4	0.0
Marquette	734	77	111	29.21	30.05	+.03	19.1	−3.8	43	1	26	−10	18	12	28	17	14	82	1.14	−1.4	16	9,347	w.	43	s.	10	6	1	24	7.8	10.6	4.2
Port Huron	638	70	120	29.37	30.09	+.03	27.0	−0.6	58	1	34	−1	18	20	30	25	22	84	1.21	−1.0	10	9,530	w.	49	w.	12	7	11	13	6.4	4.7	T.
Saginaw	641	69	77	29.37	30.09	......	25.6	......	57	1	32	−2	18	19	30	24	21	83	0.80	−1.1	11	7,566	sw.	32	sw.	12	4	7	20	8.1	3.4	T.
Sault Ste. Marie	614	11	52	29.32	30.05	+.05	19.2	−1.3	54	1	26	−11	18	12	33	17	15	87	2.30	0.0	24	7,681	e.	52	nw.	5	3	3	25	8.4	23.5	8.2
Chicago	823	140	310	29.19	30.11	+.03	29.9	−0.1	58	1	37	−3	18	22	35	27	21	68	1.21	−0.9	10	9,470	s.	36	s.	11	8	6	17	6.3	2.4	0.0
Green Bay	617	109	144	29.37	30.06	+.02	19.6	−1.7	43	3	27	−11	18	12	28	18	14	79	0.59	−1.2	10	9,435	s.	46	w.	4	9	4	18	7.1	3.6	T.
Milwaukee	681	125	139	29.32	30.09	+.03	25.6	−0.4	57	1	33	−8	18	18	28	23	18	74	1.30	−0.6	9	8,234	w.	31	se.	6	10	2	19	6.4	8.2	0.0
Duluth	1,133	11	47	28.76	30.04	−.01	11.8	−4.1	40	25	20	−18	17	4	39	10	9	91	0.90	−0.3	11	10,410	w.	67	nw.	11	12	4	15	5.8	12.0	6.0
North Dakota.							**9.1**	**−2.9**										**87**	**0.79**	**+0.2**										**6.4**		
Moorhead	940	50	58	29.00	30.07	−.01	9.4	−2.1	41	25	17	−18	18	2	37	8	6	88	0.60	−0.1	9	6,247	s.	32	nw.	4	5	8	18	7.2	6.5	5.0
Bismarck	1,674	8	57	28.23	30.12	+.04	13.0	−1.7	45	24	22	−21	9	4	41	10	7	85	0.94	+0.3	6	6,006	w.	35	nw.	11	6	17	8	5.4	12.9	8.2
Devils Lake	1,482	11	44	28.38	30.05	−.01	6.0	−2.0	41	25	14	−24	17	−2	42	4	3	90	0.87	+0.5	10	7,777	w.	36	nw.	25	8	6	17	6.4	13.4	5.9
Ellendale	1,457	10	56	28.44	30.07	......	12.2	......	43	25	20	−20	18	4	39	....	....	....	0.34	......	4	10,318	nw.	53	nw.	11	8	6	17	6.6	3.5	1.5
Grand Forks	835	12	89	......	......	......	6.2	......	39	25	14	−22	17	−2	31	6	....	....	1.01	......	8	......	w.	40	nw.	30	10	6	15	....	10.1	9.0
Williston	1,878	41	48	27.98	30.07	+.01	8.0	−5.8	43	28	16	−26	17	0	35	7	4	86	0.74	+0.1	11	5,842	w.	32	w.	25	10	4	17	6.3	10.3	2.0
Upper Mississippi Valley.							**27.5**	**+0.3**										**77**	**1.14**	**−0.6**										**6.0**		
Minneapolis	918	102	208	29.03	30.06	......	18.2	......	51	25	26	−12	17	10	38	....	....	....	0.15	−0.8	4	9,049	w.	43	nw.	11	7	11	13	6.2	1.7	T.
St. Paul	837	236	261	29.13	30.08	.00	17.8	−1.2	50	25	26	−14	18	10	35	....	....	....	0.18	−0.9	4	9,826	w.	50	w.	11	8	12	11	6.0	2.0	0.0
La Crosse	714	11	48	29.29	30.10	+.02	20.4	−1.9	47	3	29	−17	18	12	37	....	....	....	0.42	−0.9	6	4,196	se.	22	w.	11	11	5	15	5.8	4.4	0.0
Madison	974	70	78	29.01	30.11	+.03	21.6	−1.1	46	3	29	−11	18	14	32	20	17	83	1.23	−0.5	10	8,041	w.	31	w.	11	9	4	18	6.4	9.4	0.4
Wausau	1,247	4	....	28.68	30.08	......	16.1	......	39	2	24	−15	19	8	33	....	....	....	0.56	......	9	......	nw.	....	......	....	9	5	17	6.4	4.5	0.2
Charles City	1,015	10	49	28.98	30.11	+.01	19.1	+0.1	49	2	29	−21	18	9	36	17	15	86	0.43	−0.8	6	5,421	se.	28	nw.	11	11	11	9	5.3	5.8	0.0
Davenport	606	71	79	29.43	30.12	+.02	27.0	−0.2	56	25	36	−4	18	18	29	24	19	74	0.60	−1.1	7	5,960	nw.	27	nw.	11	9	8	14	6.1	0.8	T.
Des Moines	861	84	97	29.16	30.10	−.01	25.6	−0.1	53	22	35	−7	18	16	34	23	18	73	0.25	−1.1	5	5,683	nw.	26	nw.	11	12	8	11	5.2	1.9	T.
Dubuque	698	81	96	29.34	30.13	+.03	23.8	−0.9	51	3	32	−14	18	15	32	21	16	74	0.41	−1.3	8	5,194	nw.	28	nw.	4	8	7	16	6.3	3.4	T.
Keokuk	614	64	78	29.43	30.13	+.01	30.5	+1.1	63	25	40	−2	18	21	32	26	20	68	0.63	−1.2	6	6,014	nw.	29	nw.	11	10	9	12	5.6	1.3	T.
Cairo	356	87	93	29.72	30.12	−.03	41.4	+3.6	68	4	50	16	19	33	32	37	33	75	3.27	−0.1	13	7,861	s.	31	nw.	27	6	7	18	6.9	0.0	0.0
Peoria	609	11	45	29.44	30.13	+.02	28.8	+0.7	61	1	38	−6	18	20	33	26	23	85	1.38	−1.0	6	5,555	s.	22	n.	27	10	9	12	5.4	1.9	0.0
Springfield, Ill	644	10	91	29.40	30.10	−.02	32.0	+0.3	62	4	40	−2	18	24	37	28	24	77	1.59	−0.8	7	7,065	w.	26	nw.	4	6	9	16	6.7	1.2	0.0
Hannibal	534	74	109	29.53	30.13	+.01	32.3	+1.0	63	4	42	2	18	23	32	....	....	....	0.38	−1.3	6	6,611	nw.	31	n.	27	12	8	11	5.5	0.5	0.0
St. Louis	567	265	303	29.49	30.11	−.02	36.7	+1.9	67	4	45	5	18	28	37	33	28	72	4.98	+2.8	8	9,895	s.	39	s.	4	10	11	10	5.5	0.5	0.0
Missouri Valley.							**27.8**	**+0.4**										**72**	**0.44**	**−0.6**										**4.8**		
Columbia, Mo	781	11	84	29.25	30.11	−.01	34.3	+1.4	72	7	45	3	18	24	37	....	....	....	1.38	−0.6	6	6,846	se.	31	n.	27	9	13	9	5.2	0.3	0.0
Kansas City	963	161	181	29.04	30.10	−.02	34.7	+3.2	67	25	45	3	18	25	36	29	22	64	0.22	−1.1	3	8,967	s.	37	nw.	11	15	8	8	4.3	0.6	0.0
St. Joseph	967	11	49	29.02	30.10	......	31.2	......	63	25	41	1	12	22	30	27	21	70	0.16	......	3	6,690	nw.	31	nw.	11	15	10	6	4.0	0.2	0.0
Springfield, Mo	1,324	98	104	28.65	30.09	−.04	39.2	+3.7	71	7	49	12	12	30	28	34	29	74	2.07	−0.6	9	8,612	se.	33	n.	27	14	5	12	5.2	T.	0.0
Iola	984	11	50	29.01	30.09	−.03	36.0	+3.5	70	7	48	9	12	24	40	....	....	....	0.18	−0.8	2	5,785	n.	30	s.	29	9	9	13	5.7	T.	0.0
Topeka	987	92	107	......	......	......	32.8	+1.7	68	25	44	3	12	22	34	....	....	....	0.06	−0.8	2	7,780	n.	37	s.	29	17	7	7	4.1	T.	0.0
Drexel	1,299	10	53	28.65	30.09	......	25.0	......	57	24	36	−7	17	14	37	....	....	....	0.08	......	3	8,131	nw.	33	s.	29	12	11	8	5.1	1.0	0.0
Lincoln	1,189	11	84	28.79	30.11	−.01	28.1	+1.2	63	25	39	−3	17	17	38	23	17	68	0.06	−0.6	3	7,470	se.	34	s.	11	15	11	5	3.9	0.2	0.0
Omaha	1,105	115	122	28.88	30.12	+.01	27.2	+0.1	58	29	37	−5	17	18	35	24	18	70	0.07	−0.8	3	6,167	nw.	37	nw.	4	13	9	9	5.1	0.5	0.0
Valentine	2,598	47	54	27.27	30.10	.00	22.6	−1.9	59	28	34	−16	17	11	44	18	14	74	0.43	−0.2	7	6,189	w.	35	nw.	30	12	15	4	4.3	6.7	0.0
Sioux City	1,135	94	164	28.84	30.11	−.01	23.1	+0.5	53	29	33	−12	17	14	38	20	14	69	0.07	−0.7	2	8,978	nw.	46	nw.	11	11	9	11	5.2	0.7	0.0
Huron	1,306	59	74	28.66	30.13	+.03	17.0	−1.7	47	23	27	−22	17	8	46	14	11	80	0.22	−0.4	5	6,752	se.	30	w.	11	12	6	13	5.4	2.2	0.2
Pierre	1,572	70	75	28.37	30.12	+.02	16.4	−5.4	48	24	26	−22	18	7	54	14	10	78	0.31	−0.2	5	4,979	nw.	40	nw.	11	11	9	11	5.1	5.7	0.5
Yankton	1,233	49	57	28.73	30.12	+.01	21.6	−1.3	54	3	32	−16	17	11	46	....	....	....	0.20	−0.5	2	5,701	w.	33	nw.	11	11	10	10	5.3	2.5	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, December, 1922*—Continued.

Districts and stations.	Elevation of instruments: Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Pressure: Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Temperature of the air: Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity.	Precipitation: Total.	Departure from normal.	Days with 0.01 inch, or more.	Wind: Total movement.	Prevailing direction.	Maximum velocity: Miles per hour.	Direction.	Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet, and ice on ground at end of month.
	Ft.	Ft.	Ft.	In.	In.	In.	° F.	° F.	° F		° F	° F.		° F	° F.	° F.	° F.	%	In.	In.		Miles.								0–10	In.	In.
Northern Slope.							20.2	−3.4										72	0.74	−0.1										6.4		
Billings	3,140	5	....	....	....	....	19.2	....	59	24	30	−27	12	9	48	....	....	....	0.35	....	....	....	nw.	....	....	....	9	11	11	....	3.8	....
Havre	2,505	11	44	27.32	30.11	+.06	11.4	−9.0	56	24	20	−35	12	2	61	9	7	81	0.53	−0.1	8	6,358	sw.	42	sw.	19	5	10	16	6.8	5.3	0.5
Helena	4,110	87	112	25.73	30.10	−.03	18.2	−6.6	54	23	27	−23	12	9	50	14	11	78	1.09	+0.3	12	5,002	sw.	40	sw.	29	3	3	25	7.9	19.3	T.
Kalispell	2,973	48	56	26.88	30.06	−.01	18.3	−5.6	47	24	25	−19	14	12	31	17	14	81	1.50	−0.4	20	3,632	nw.	32	w.	10	2	3	26	8.5	11.4	2.5
Miles City	2,371	48	55	27.47	30.15	+.05	14.0	−7.0	47	24	23	−30	17	5	38	11	8	69	0.80	+0.2	9	4,104	sw.	24	nw.	1	9	8	14	6.2	7.6	3.0
Rapid City	3,259	50	58	26.55	30.13	+.04	22.8	−3.2	59	28	33	−16	17	12	46	17	11	66	0.28	−0.2	5	4,893	w.	34	n.	11	11	10	10	5.3	3.0	0.1
Cheyenne	6,088	84	101	23.89	30.02	−.07	29.5	+0.5	52	6	39	−1	14	20	34	24	17	62	0.44	+0.1	4	11,414	w.	60	w.	24	9	12	10	5.3	4.8	T.
Lander	5,372	60	68	24.54	30.07	−.08	21.6	+2.4	48	28	33	−9	17	11	31	18	12	66	0.03	−0.7	2	3,634	sw.	64	sw.	10	10	16	5	5.1	0.3	T.
Sheridan	3,790	10	47	26.04	30.11	....	17.0	....	61	24	29	−25	17	5	44	13	8	72	1.02	....	9	3,407	nw.	35	nw.	19	7	15	9	6.0	7.0	2.0
Yellowstone Park	6,200	11	48	23.77	30.10	−.06	18.6	−3.0	41	24	27	−16	14	11	35	16	13	78	1.98	+0.2	19	7,328	s.	40	s.	5	3	5	23	8.3	23.6	13.8
North Platte	2,821	11	51	27.09	30.13	+.03	27.8	+1.1	62	24	41	−6	12	15	42	21	16	69	0.01	−0.5	1	4,699	w.	25	n.	11	13	10	8	5.0	0.1	0.0
Middle Slope.							36.0	+3.0										65	0.20	−0.6										4.5		
Denver	5,292	106	113	24.63	29.99	−.09	35.1	+2.8	64	24	47	7	12	24	36	28	18	56	0.63	0.0	2	5,364	s.	32	w.	23	14	15	2	4.0	4.8	0.4
Pueblo	4,685	80	86	25.23	30.00	−.08	36.5	+4.8	65	28	52	6	18	21	44	28	18	53	T.	−0.5	0	4,686	w.	42	w.	29	15	13	3	4.0	T.	0.0
Concordia	1,392	50	58	28.58	30.10	−.01	31.4	+1.9	62	22	42	0	17	20	34	26	20	71	T.	−0.5	0	6,007	n.	32	n.	26	10	12	9	5.1	0.0	0.0
Dodge City	2,509	11	51	27.42	30.11	+.01	33.7	+2.1	67	6	48	2	17	20	46	26	19	65	T.	−0.6	0	6,958	nw.	37	n	26	18	6	7	3.6	T.	0.0
Wichita	1,358	139	158	28.59	30.06	−.05	36.4	+2.2	65	25	47	8	17	26	36	31	24	66	0.06	−0.7	1	9,515	s.	38	s.	29	18	5	8	4.1	T.	0.0
Altus	1,410	5	....	....	....	....	46.4	....	78	3	61	16	19	32	45	....	....	....	0.59	....	2	....	n.	....	....	....	20	3	8	....	~~0.0~~	~~0.0~~
Broken Arrow	765	11	52	29.25	30.09	....	42.2	....	74	7	53	18	12	32	39	....	....	....	1.72	....	4	9,919	n.	42	s.	29	10	9	12	5.7	0.0	0.0
Muskogee	652	4	....	....	....	....	45.0	....	77	7	56	21	12	34	40	....	....	....	2.20	....	8	....	se.	....	....	....	12	8	11	....	0.0	0.0
Oklahoma City	1,214	10	47	28.77	30.08	−.03	42.6	+4.0	73	25	53	18	12	32	35	36	30	67	0.53	−1.2	2	9,048	s.	36	n.	27	14	8	9	4.8	0.0	0.0
Southern Slope.							47.9	+4.2										56	0.09	−0.8										4.2		
Abilene	1,738	10	52	28.24	30.08	−.03	49.4	+4.4	78	7	62	18	19	37	43	40	31	59	0.20	−0.9	1	6,952	s.	38	nw.	26	13	6	12	5.2	0.0	0.0
Amarillo	3,676	10	49	26.26	30.05	−.03	41.8	+5.4	72	28	56	9	17	28	45	33	26	62	0.10	−0.7	2	8,113	sw.	36	n.	26	17	10	4	3.9	0.1	0.0
Del Rio	944	64	71	29.07	30.07	−.03	56.1	+3.7	78	25	68	28	19	44	41	....	....	....	0.04	−0.9	1	4,998	se.	44	nw.	26	14	8	9	4.4	0.0	0.0
Roswell	3,566	75	85	26.38	30.04	−.03	44.4	+3.2	72	7	50	15	19	29	45	35	22	46	0.01	−0.5	1	4,878	nw.	32	nw.	30	18	6	7	3.5	0.0	0.0
Southern Plateau.							44.9	+2.9										65	0.24	−0.4										3.3		
El Paso	3,762	110	133	26.24	30.05	+.02	49.2	+4.4	69	13	61	27	19	37	34	39	26	45	0.09	−0.4	2	6,517	nw.	37	nw.	30	20	9	2	2.5	0.0	0.0
Santa Fe	7,013	38	53	23.23	30.09	+.03	34.0	+3.7	51	23	43	12	31	25	29	27	22	66	0.20	−0.6	3	4,387	n.	25	n.	26	17	8	6	3.5	T.	0.0
Flagstaff	6,908	10	59	23.35	30.05	−.01	33.0	+4.6	56	24	44	4	9	22	39	27	....	72	1.50	....	10	5,780	w.	26	sw.	7	15	6	10	....	1.2	T.
Phoenix	1,108	11	81	28.89	30.06	+.02	55.0	+3.1	74	20	67	34	30	43	37	47	40	66	0.28	−0.3	2	2,622	e.	15	w.	29	14	13	4	3.4	0.0	0.0
Yuma	141	9	54	29.92	30.07	+.02	57.3	+2.1	74	24	70	36	31	45	33	51	45	69	0.08	−0.4	2	2,415	n.	17	w.	7	21	7	3	2.7	0.0	0.0
Independence	9,537	9	41	26.02	30.12	.00	41.0	−0.6	62	28	52	18	9	30	35	34	29	70	0.57	−0.2	9	3,069	nw.	40	w.	28	14	10	7	4.6	0.5	0.0
Middle Plateau.							33.3	+2.0										78	1.58	+0.6										6.9		
Reno	4,532	74	81	25.48	30.11	−.04	35.0	+1.3	60	27	43	5	2	26	36	31	28	79	3.03	+1.4	14	3,811	w.	56	se.	27	5	10	16	6.7	11.2	T.
Tonopah	6,090	12	20	24.07	30.10	....	34.1	....	50	24	40	16	8	29	19	31	27	74	0.28	−0.5	6	5,806	se.	37	nw.	31	6	12	13	6.1	3.3	0.0
Winnemucca	4,344	18	56	25.64	30.13	−.05	30.9	+0.2	50	5	39	2	9	23	33	28	25	81	1.91	+0.9	13	5,077	sw.	50	sw.	6	4	3	24	8.1	11.1	0.0
Modena	5,479	10	43	24.63	30.08	−.04	33.2	+1.5	55	27	42	9	30	25	33	29	26	77	0.61	0.0	6	6,623	sw.	51	sw.	28	5	12	14	6.6	1.4	0.1
Salt Lake City	4,360	163	203	25.66	30.12	−.03	33.1	+1.2	50	6	38	17	17	28	19	30	27	78	2.92	+1.6	14	4,138	se.	44	s.	10	4	8	19	7.8	24.1	6.4
Grand Junction	4,602	60	68	25.42	30.07	−.03	34.2	+6.0	52	6	43	16	26	25	28	30	26	77	0.71	+0.3	10	3,450	se.	28	w.	20	8	7	16	5.9	5.0	0.3
Northern Plateau.							27.6	−4.4										81	2.04	+0.3										8.3		
Baker	3,471	48	53	26.43	30.12	−.04	24.3	−3.1	47	24	32	−4	12	17	26	23	21	84	1.74	+0.2	15	4,753	se.	30	s.	9	0	6	25	8.5	12.3	3.0
Boise	2,739	78	86	27.23	30.17	−.03	30.0	−2.2	55	27	37	−2	16	24	22	27	23	74	1.73	0.0	14	4,106	se.	39	se.	31	2	5	24	8.5	6.9	0.0
Lewiston	757	40	48	29.24	30.08	−.05	31.0	−6.5	60	24	37	−1	17	25	22	....	....	....	1.33	−0.2	15	2,749	e.	24	nw.	10	2	4	25	8.6	7.8	0.0
Pocatello	4,477	60	68	25.47	30.13	−.06	27.2	−1.2	46	27	34	−5	15	21	24	25	21	77	1.82	+1.0	10	8,547	s.	43	s.	10	2	8	21	7.8	19.5	6.0
Spokane	1,929	101	110	27.96	30.09	+.01	22.4	−8.1	49	27	28	−15	16	17	21	22	21	91	3.81	+1.2	20	3,774	sw.	28	sw.	24	3	3	25	8.3	31.0	0.1
Walla Walla	991	57	65	28.98	30.09	−.03	30.8	−5.2	62	24	38	−2	14	24	29	28	24	79	1.83	−0.3	17	4,390	s.	28	se.	30	2	5	24	8.3	13.4	0.0
North Pacific Coast Region.							39.7	−2.4										86	8.28	+0.7										8.4		
North Head	211	11	56	29.71	29.94	−.09	41.4	−2.8	54	20	45	25	12	38	13	40	38	88	8.60	+1.1	22	16,105	s.	78	s.	30	4	2	25	8.2	2.2	0.0
Port Angeles	29	8	53	29.93	29.96	....	36.0	....	54	23	40	20	15	31	16	....	....	....	7.73	+2.6	24	4,799	s.	42	ne.	6	0	6	25	8.9	18.3	0.0
Seattle	125	215	250	29.85	29.99	−.02	38.4	−2.8	56	24	43	19	12	34	17	36	34	82	7.37	+2.1	22	9,228	s.	54	sw.	31	3	4	24	8.4	11.2	0.0
Tacoma	213	113	120	29.76	29.98	−.03	38.0	−2.3	58	23	43	15	12	33	18	....	....	....	7.12	−0.1	20	5,389	sw.	37	sw.	24	1	6	24	8.4	8.0	0.0
Tatoosh Island	86	7	57	29.79	29.88	−.08	40.4	−3.5	52	27	43	29	11	38	16	39	38	90	11.78	−2.8	29	18,872	e.	76	ne.	5	0	7	24	8.7	4.0	0.0
Yakima	1,071	4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Medford	1,425	4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Portland, Oreg.	153	68	106	29.86	30.02	−.05	38.0	−3.2	61	23	42	18	14	34	23	36	33	83	9.43	+2.1	25	5,524	se.	26	sw.	9	4	1	26	8.5	7.9	0.0
Roseburg	510	9	57	29.51	30.06	−.05	42.2	+0.4	61	26	47	26	14	37	17	40	38	85	5.86	−0.1	21	2,288	s.	23	sw.	5	1	11	19	7.9	0.0	0.0
Middle Pacific Coast Region.							48.1	−0.6										84	6.36	+1.8										7.1		
Eureka	62	73	89	30.03	30.10	−.02	47.6	−0.4	64	22	54	35	8	42	24	45	42	83	7.62	+0.4	22	4 666	se.	49	sw.	30	3	6	22	8.0	0.0	0.0
Point Reyes	490	7	18	29.54	30.06	....	49.8	−0.8	62	20	54	40	8	46	19	....	....	....	5.43	....	16	12,889	s.	81	s.	9	6	9	16	6.8	0.0	0.0
Red Bluff	332	50	56	29.76	30.13	−.01	43.7	−2.4	66	21	50	28	8	37	29	42	39	82	5.59	+1.1	19	3,135	nw.	33	se.	6	5	10	16	7.1	3.5	0.0
Sacramento	69	106	117	30.06	30.13	−.01	47.4	+1.2	59	19	52	30	4	43	22	46	43	86	6.12	+2.6	19	4,872	se.	44	se.	9	5	9	17	7.2	0.0	0.0
San Francisco	155	208	243	29.94	30.11	−.01	50.6	−0.7	61	13	55	41	23	46	15	48	46	87	7.77	+3.5	17	5,572	se.	38	se.	9	8	4	19	6.7	0.0	0.0
San Jose	141	12	110	29.97	30.13	....	49.4	−0.5	64	10	57	31	4	42	29	....	....	....	4.68	+1.6	15	4,273	se.	43	se.	9	7	7	17	6.6	0.0	0.0
South Pacific Coast Region.							55.1	+2.1										78	3.28	+1.2										6.1		
Fresno	327	89	98	29.79	30.16	+.03	49.8	+3.0	64	27	56	34	8	44	29	48	45	83	2.20	+0.7	13	3,626	nw.	24	nw.	31	2	3	26	8.5	0.0	0.0
Los Angeles	338	159	191	29.74	30.11	+.04	58.3	+1.7	80	21	66	44	9	51	26	52	47	74	3.09	+0.2	14	3,960	e.	24	nw.	31	13	5	13	5.0	0.0	0.0
San Diego	87	62	70	29.99	30.09	+.02	58.0	+2.0	74	21	65	41	9	51	24	53	49	78	1.21	−0.6	8	3,916	nw.	28	s.	10	11	8	12	5.5	0.0	0.0
San Luis Obispo	201	32	40	29.90	30.12	+.01	54.4	+1.6	75	24	64	35	8	45	37	49	45	78	6.64	+4.3	16	2,973	n.	27	ne.	24	11	7	13	5.4	0.0	0.0
West Indies.																																
San Juan, P. R.	82	8	54	29.96	30.05	....	75.2	....	81	9	80	68	12	71	12	....	....	....	12.65	+6.5	25	12,257	e	48	e.	1	9	14	8	5.3	0.0	0.0
Panama Canal.																																
Balboa Heights	118	7	97	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Colon	36	7	97	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Alaska.																																
Juneau	80	11	54	....	....	....	28.0	....	43	20	32	14	31	24	17	25	19	70	2.16	....	13	5,700	e.	39	e.	5	11	1	19	6.5	18.1	5.0

LATE REPORT, PANAMA CANAL, NOVEMBER, 1922.

Balboa Heights	118	7	97	29.73	29.85	+.01	78.6	−0.5	88	21	84	71	20	73	17	74	73	87	8.44	−1.8	21	3,663	nw.	24	ne.	3	0	13	17	7.7	0.0	0.0
Colon	36	7	97	29.82	29.85	.00	79.4	+0.3	89	3	85	72	5	74	14	75	74	84	15.63	−5.3	25	5,584	n.	31	nw.	12	1	9	20	8.1	0.0	0.0

TABLE 2.—*Data furnished by the Canadian Meteorological Service, December, 1922.*

Stations.	Altitude above mean sea level, Jan. 1, 1919.	Pressure.			Temperature of the air.						Precipitation.		
		Station reduced to mean of 24 hours.	Sea level reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Mean maximum.	Mean minimum.	Highest.	Lowest.	Total.	Departure from normal.	Total snowfall.
	Feet.	In.	In.	In.	° F.	° F.	° F.	° F.	° F.	° F.	In.	In.	In.
St. Johns, N. F	125												
Sydney, C. B. I	48	29.96	30.01	+.12	23.7	−4.5	30.0	17.5	46	4	5.90	+1.27	38.0
Halifax, N. S	88	29.94	30.05	+.09	24.0	−3.6	31.8	16.3	47	−6	5.59	+0.47	24.3
Yarmouth, N. S	65												
Charlottetown, P. E. I	38	29.96	30.00	+.06	20.5	−3.8	28.4	12.6	44	−10	2.71	−0.95	24.5
Chatham, N. B	28	29.96	30.00	+.06	12.2	−4.8	22.9	1.6	40	−26	3.46	+0.24	28.6
Father Point, Que	20	30.05	30.08	+.13	10.9	−4.5	20.1	1.7	30	−19	2.16	−0.67	21.0
Quebec, Que	296	29.77	30.12	+.11	14.1	−1.1	21.8	6.5	46	−18	3.19	−0.50	28.0
Montreal, Que	187	29.88	30.10	+.07	18.3	0.0	24.9	11.8	52	−8	1.78	−1.87	15.0
Stonecliffe, Ont	489												
Ottawa, Ont	236	29.83	30.12	+.10	18.4	+1.4	26.6	10.3	54	−11	1.79	−1.12	15.4
Kingston, Ont	285	29.78	30.11	+.07	25.3	+1.6	32.2	18.4	55	1	0.97	−2.27	4.6
Toronto, Ont	379	29.67	30.10	+.05	28.4	+1.4	34.9	21.9	60	6	1.72	−1.19	11.8
Cochrane, Ont	930												
White River, Ont	1,244	28.58	29.97	.00	2.4	−7.3	17.2	−12.4	45	−49	1.99	+0.28	19.9
Port Stanley, Ont	592	29.48	30.14	+.07	27.0	−1.4	35.1	19.0	52	0	1.20	−1.22	9.5
Southampton, Ont	656	29.31			26.3	−0.4	32.3	20.3	55	8	2.83	−1.15	22.5
Parry Sound, Ont	688	29.32	30.05	+.04	21.8	+0.6	30.1	13.5	53	−5	4.00	−0.48	24.4
Port Arthur, Ont	644	29.28	30.02	+.03	10.6	−2.6	19.7	1.5	40	−27	1.37	+0.50	13.7
Winnipeg, Man	760	29.19	30.09	+.07	2.6	−1.5	9.5	−4.4	36	−26	1.39	+0.48	13.7
Minnedosa, Man	1,690	28.11	30.04	+.02	−0.7	−6.4	7.0	−8.3	31	−34	0.59	−0.03	5.9
Le Pas, Man	860				−2.6		4.2	−9.3	34	−30	0.22		2.2
Qu'Appelle, Sask	2,115	27.63	30.00	.00	2.8	−4.6	11.1	−5.5	40	−30	1.06	+0.54	9.4
Medicine Hat, Alb	2,144	27.61	29.97	.00	15.1	−3.1	24.6	5.6	51	−38	0.71	+0.16	7.1
Moose Jaw, Sask	1,759				4.9		11.7	−1.8	40	−30	0.77		7.0
Swift Current, Sask	2,392	27.32	30.09	+.10	7.4	−8.6	15.3	−0.5	45	−29	0.41	−0.37	4.1
Calgary, Alb	3,428												
Banff, Alb	4,521	25.22	30.04	+.10	7.9	−11.2	15.2	0.5	40	−36	0.71	−0.50	6.0
Edmonton, Alb	2,150												
Prince Albert, Sask	1,450	28.40	30.08	+.07	1.3	−1.5	9.0	−6.4	38	−30	0.41	−0.33	4.1
Battleford, Sask	1,592	28.18	30.02	+.03	3.9	−1.5	12.2	−4.3	43	−26	0.44	+0.12	4.4
Kamloops, B. C	1,262												
Victoria, B. C	230	29.68	29.94	−.03	37.0	−4.2	40.2	33.8	55	21	7.15	−0.83	16.7
Barkerville, B. C	4,180												
Triangle Island, B. C	680												

LATE REPORTS FOR NOVEMBER, 1922.

St. Johns, N. F	125	29.48	29.62	−.32	34.7	−1.8	38.6	30.8	48	18	5.32	−0.25	5.0
Winnipeg, Man	760	29.19	30.06	+.02	32.2	+14.2	38.4	26.1	54	6	2.42	+1.34	6.4
Medicine Hat, Alb	2,144	27.70	30.03	+.03	31.1	+3.7	43.9	18.4	62	−3	0.32	−0.60	2.4
Calgary, Alb	3,428	26.45	30.12	+.14	31.6	+5.8	47.8	15.5	65	−3	0.19	−0.69	1.8
Banff, Alb	4,521	25.44	30.18	+.22	25.2	−0.6	34.8	15.8	42	−1	0.42	−1.85	2.3
Edmonton, Alb	2,150	27.67	30.12	+.15	29.1	+6.2	38.1	20.1	52	−5	0.23	−0.35	2.3
Kamloops, B. C	1,262	28.93	30.26	+.30	35.5	+2.1	40.7	30.4	50	21	0.23	−1.23	T.
Barkerville, B. C	4,180	25.66	30.04	+.14	27.8	+4.2	34.1	21.5	43	10	3.16	−0.13	20.5
Hamilton, Ber	151	29.89	30.06	+.01	65.3	+3.4	72.2	58.5	79	52	3.67	−0.71	

SEISMOLOGICAL REPORTS FOR DECEMBER, 1922.

W. J. HUMPHREYS, Professor in Charge.

[Weather Bureau, Washington, February 3, 1923.]

TABLE 1.—*Noninstrumental earthquake reports, December, 1922.*

Day.	Approximate time, Greenwich civil.	Station.	Approximate latitude.	Approximate longitude.	Intensity Rossi-Forel.	Number of shocks.	Duration.	Sounds.	Remarks.	Observer.
		CALIFORNIA.								
1922.	H. m.		° ′	° ′			Sec.			
Dec. 8		San Francisco	37 48	122 26			5			Press report.
14	5 15	Yorba Linda	33 50	117 45	2	1		None		P. J. Ton.
29	11 ca.	Paso Robles	35 40	120 45	2	1	2	....do	Felt by several	Anna Z. Campbell.
	12 ca.	....do	35 40	120 45	2	1	2	....do	....do	Do.
		MONTANA.								
19	4 40	Helena	46 40	112 00	3-4	1	1-2	Rumbling	Felt by many	W. T. Lathrop.
	4 45	Missoula	46 55	114 00	3	1	Few.		....do	M. J. Elrod.
		NEW YORK.								
8	21 24	Canton	44 30	75 10	5	2	15-20	Rumbling	Felt by many	J. S. Hazen.

TABLE 2.—*Instrumental seismological reports, December, 1922.*

Time used: Mean Greenwich, midnight to midnight. Nomenclature: International.

For significance of symbols and description of stations, see REVIEW for January, 1922.

ALASKA. *U. S. C. & G. S. Magnetic Observatory, Sitka.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1922.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Dec. 31		O	7 19 40				5,070	M_N occurs during SR1; P very weak.
		P_E	7 28 12	9				
		S_E	7 34 58					
		S_N	7 35 05					
		$SR1_E$	7 38 16					
		$SR2_E$	7 38 24					
		$L1_E$	7 42 20					
		$L2_E$	7 49 02					
		L_N	7 49 34					
		M_E	7 43 34		*500			
		M_N	7 39 21	18		*200		
		F_E	8 08 —					
		F_N	8 16 —					

CALIFORNIA. *Theosophical University, Point Loma.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1922.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Dec. 22					50	50		Tremors during preceding 24 hours.

DISTRICT OF COLUMBIA. *U. S. Weather Bureau, Washington.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1922.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Dec. 6		e	14 20 20					
		F	14 27 *ca.*					
15		eL	0 10 —					
		F	0 30 —					
17		e	1 15 —					
		F	1 20 —					
18		P	12 40 57				2,500	
		S	12 44 58					
		eL	12 49 —					
		L	12 50 —	12				
		F	13 05 *ca.*					
31		eL	8 03 —					
		L	8 06 54	20				
		L	8 16 —	16				
		F	8 30 —					

HAWAII. *U. S. C. & G. S. Magnetic Observatory, Honolulu.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1922.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Dec. 14		ePe?	23 15 30					Greater part of EW record obscured by overlapping of traces.
		PR_E	23 17 45					
		S	23 22 05	15				
		L_N	23 32 00					
		M_N	23 33 36	13		35		
		C_N	23 44 ..					
15		F_N	0 19 ..					
19		e_E	18 03 40					Poorly defined.
		e_N	18 04 30					
		e_E	18 07 38					
		e_N	18 05 43					
		M_E	18 09 45	8	15			
		M_N	18 08 25	18		56		
		F_E	18 16 ..					
		F_N	18 17 ..					
23		e_E	22 15 08					Poorly defined; NS partly obscured by overlap.
		e_N	22 18 15					
		e_E	22 17 50					
		e_N	22 25 20	16				
		F_E	22 23 ..					
31		O	7 19 54				5,310	
		P_E	7 28 42					
		iS_E	7 35 41					
		S_N	7 35 45					
		$SR1_E$	7 39 42					
		$SR1_N$	7 39 30					
		L_E	7 41 45	27				
		L_N	7 41 50	25				
		M_E	7 48 23	19	53			
		M_N	7 48 38	18		48		
		F_E	8 54 ..					
		F_N	8 24 ..					

* Trace amplitude.

ILLINOIS. *U. S. Weather Bureau, Chicago.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1922.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Dec. 2		e_E	4 39 00					
		eL	4 46 20					
		F	5 10 *ca*					
6		P?	14 18 03					
		PR1	14 20 43					
		S?	14 27 00					
		L	14 39 50	20				
		F	15 20 *ca*					
7		e	15 21 00					
		eL	15 23 ..	20				
		F	15 45 ..					
7		e	17 37 *ca*					
		eL	17 46 ..					
		F	18 15 *ca*					
8		P?	22 56 08					
		eL	23 23 ..					
		L	23 31 ..	18				
		F	23 50 ..					
14		e	23 33 40					
15		L	0 00 30					
		L	0 03 ..	20				
		L	0 15 ..	18				
		F	1 40 *ca*					
17		e	1 04 35					
		eL	1 33 ..					
		F	2 10 *ca*					
18		P	12 41 00					
		S	12 45 50				3,100	
		L	12 48 50	15				
		F	15 10 *ca*					
18		e	21 21 42					
		eL	21 28 50					
		F	22 *ca* ..					
19		e	18 08 07					
		eL	18 20 ..					
		L	18 26 30	16				
		F	19 10 ..					
23		P?	22 20 30					
		S?	22 28 55					
		L	22 47 ..	15				
		F	23 40 *ca.*					
24		e	17 45 18					
		F	17 53 ..					
25		e	4 10 25					
		L	4 32 00	18				
		L	4 40 ..	15				
		F	6 02 ca.					
25		eL	12 23 ..					
		F	13 *ca.*					
31		P	7 41 57				3,400	
		S	7 47 08					
		L	7 50 18	16				
		L	8 08 ..	15				
		F	10 20 ..					

MARYLAND. *U. S. C. & G. S. Magnetic Observatory, Cheltenham.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1922.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Dec. 18		O	12 34 45				2,500	E record very weak.
		P_N	12 39 52	2				
		S	12 43 57					
		L_E	12 55 26					
		L_N	12 49 04					
		M_N	12 49 48	12	*100			
		F_E	12 04 ..					
		F_N	12 58 ..					
31		e_E	7 42 46					Record very faint; e rarely perceptible.
		S_E?	7 43 34					
		L_E	8 01 46					
		F_E	8 06 ..					

VERMONT. *U. S. Weather Bureau, Northfield.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1922.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Dec. 6		e	14 22 ..					
		F	14 32 *ca*					
18		e	12 42 ..					
		eL	12 48 20	14				
		F	13 05 ..					
31		eL	8 05 ..					
		F	8 25 ..					

* Trace amplitude.

CANAL ZONE. *Panama Canal, Balboa Heights.*

1922			H. m. s.	Sec.	μ	μ	Km.	
Dec. 8		P	8 10 34				600	Direction NW.
		S_E	8 11 42					
		S_N	8 11 34					
		L_E	8 12 14					
		L_N	8 12 10					
		M_E	8 12 00		*2,000			
		M_N	8 12 04			*3,000		
		F_E	8 16 00					
		F_N	8 17 40					
18								Slight tremors; 12:38:44 to 12:45:00; probably local.
28		P_E	17 20 52				440ca.	Probably NW.
		S_E	17 21 40					
		S_N	17 21 40					
		M_E	17 22 08		*800			
		M_N	17 21 54			*1,000		
		F_E	17 25 00					
		F_N	17 25 30					
29								Very slight tremor, 16:35 to 16:39; probably local.
30								Very slight tremors from distant disturbance shortly after 3:00; distance and direction unknown.

PORTO RICO. *U. S. C. & G. S. Magnetic Observatory, Vieques.*

1922.			H. m. s.	Sec.	μ	μ	Km.	
Dec. 18		P_E	12 35 31					Tremors, 2 sec. period ca., superposed on P waves; felt in Porto Rico; recorded on magnetograph.
		P_N	12 35 34	7				
		L_E	12 35 43	15				
		L_N	12 36 08	17				
		M_E	12 36 19	13	*7,800			
		M_N	12 36 37	16		*15,000		
		F_E	13 12 ..					
		F_N	12 54 ..					
27		e	3 42 38	2				Local tremors.
		F_E	3 48 ..					
		F_N	3 49 ..					

CANADA. *Dominion Observatory, Ottawa.*

1922.			H. m. s.	Sec.	μ	μ	Km.	
Dec. 2		e	4 39 22					
		eL_E	4 43 30					
		F	5 ca.					
6		eL_E	14 30 ..					
		L	14 38 ..					
		F	15 00 ca.					
13		eL	5 29 ..					
		F_E	5 35 ca.					
14		O	23 19 23				8,800	
		eP	23 31 25					
		eS	23 41 25					
		eL	23 55 ..	43				
15		L	0 10 ..	19				
		L	0 20 ..	17				
		L	0 30 ..	15				
		L	0 42 ..	14				
		L	0 58 ..	13				
		L	1 12 ..					
		F	1 50 ..					
17		e_E	1 12 58					Not well defined.
		e_E	1 14 22					
		eLE	1 29 30					
		F	2 00 ..					
18		$e?_E$	12 27 41					
		e	12 40 58					
		e	12 45 ..					
		eL	12 47 ..					Irregular faint outcrops of L waves; small amplitudes after 13 hr.
		L	12 50 ..	15				
		L	13 05 ..					
		L	13 14 ..					
		F	13 40 ..					
18		e	21 24 46					Faint.
		eL	21 32 ..					
		L	21 35 ..					
		F						Lost in micros.
19		e?	18 17 ..					Small traces only.
		e_E	18 18 48					
		eL_E	18 20 ..					
		L_E	18 22 30					
		L	18 29 ..	20				
		F						Lights turned off.

* Trace amplitude.

CANADA. *Dominion Observatory, Ottawa*—Continued.

1922.			H. m. s.	Sec.	μ	μ	Km.	
Dec. 23		e	22 50 ..					
		eL	22 54 ..					
		L	23 00 to.					
			25 18 ..					
		F						Lost in micros.
25		e_E	4 05 ..					
		e_E	4 11 ..					
		eL_E	4 37 24					
		L_E	4 39 ..	20				
		L_E	4 48 ..	16				
		F	5 00 ca.					
25		e	12 18 ..					
		eL	12 21 ..					
		L	12 28 to					
			12 39 ..					
		F	12 55 ..					
25		eL	14 41 ..					
		F	15 00 ca.					
31		e_E	7 31 45					
		e_E	7 35 24					
		S_E	7 42 15					
		$eL?_E$	7 53 ..					
		L_E	8 00 ..	22				
		M_E	8 10 ..	18				
		L	8 13 ..					
		F	9 00 ..					

CANADA. *Dominion Meteorological Service, Toronto.*

1922.			H. m. s.	Sec.	μ	μ	Km.	
Dec. 2		eL	4 52 00					
		eL	5 00 36					
		M	5 01 12		*200			
		F	5 19 30					
6		L	14 34 36					Minute waves of disturbance.
		L	14 53 54		*100			
7		iL	15 20 12					
		M	15 21 24					
		eL	15 31 42		*300			
		F	15 54 00					
7		L	16 31 00					
		M	16 32 00		*200			
		F	16 34 00					
7		L	17 42 12					
		eL	17 45 24		*200			
8		L	8 28 48					
		F	8 33 42		*200			
8		e	23 06 42					
		eL	23 25 12					
		M	23 30 36		*400			
9		F	0 19 48					
14		L	0 01 36					
		eL	0 08 06					
		eL	0 12 06					
		M	0 25 30		*800			
		F	1 35 30					
17		L	1 41 00		*50			
18		eL	12 47 00					
		iL	12 49 12					
		L	12 51 42					
		M	12 52 30		*700			
		eL	12 58 48					
		F	13 29 06					
19		eL	18 28 00					
		M	18 29 06		*200			
		F	18 43 24					
23		L	22 51 36					At great distance.
		eL	22 54 12					
		M	22 59 18		*400			
		F	23 43 06					
25		L	4 40 36					Quake reported from Wellington, N. Z.
		eL	4 43 18					
		M	4 47 48		*400			
		eL	5 02 18					
		eL	5 13 24					
		F	5 44 54					
25		L	12 37 36					Barely noticeable.
		F	12 41 12					
31		iS	7 42 30					P not recorded. Distant quake.
		L	7 53 42					
		L	7 57 48					
		eL	8 04 42					
		iL	8 09 54					
		iL	8 16 48					
		M	8 19 54		*800			
		eL	8 21 24					
		eL	8 25 30					
		F	9 20 54					

* Trace amplitude.

CANADA. *Dominion Meteorological Service, Victoria.*

1922.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Dec. 2		L	0 41 35	20				
		M	0 45 00	20	3			
		F	0 50 40					
2		P	4 09 55	6				
		L	4 34 55	20				
		M	4 38 25	20	6			
		F	4 59 03	20				
6		P	14 20 31	6			2,760	
		S	14 24 56	12				
		L	14 30 31	15	6			
		M	14 40 16	15				
		F	15 08 01					
7		P	15 09 31	7			1,850	
		S	15 12 41	10				
		L	15 17 36	15				
		M	15 19 41	15	4			
		F	15 24 41					
7		L	17 36 13	16				
		M	17 37 31	18	9			
		F	17 59 01					
8		L	8 39 31					
		M	8 44 11	15	5			
		F	8 47 01					
8		P	22 44 03	6			6,700	
		S	22 52 16	10				
		L	23 03 31	30				
		M	23 07 36	20	11			
		F	23 50 56					
9		L	8 44 05	12				
		M	8 44 20	12	3			
		F	8 51 23					
12		P	20 05 47	6				May be A. C.
		L	20 09 42	12				
		M	20 13 57	12	1			
13		P	5 06 22	10				May not be quake.
		L	5 10 07	12				
		M	5 14 32	12	1			
		F	5 24 42					
14		P	23 27 47	5			5,150	
		S	23 34 37	10				
		L	23 47 22	20				
15		M	0 02 50	17	16			
		F	1 41 17					
16		M?	11 02 06	7	1			May not be quake.
		F	11 14 45					
17		L	1 16 15	16				
		M	1 17 40	12	2			
		F	2 04 40					
18		P	12 51 55	6				
		L	13 04 18	12				
		M	13 11 45	16	11			
		F	14 02 44					
18		L	21 16 33	15				
		M	21 17 32	15	5			
		F	21 27 57					
19		P	18 02 23	7				
		L	18 06 16	20				
		M	18 07 21	18	9			
		F	18 51 15					
23		P	22 17 52	7				
		L	22 35 38	16				
		M	22 38 40	16	5			
		F	23 38 05					
24		L	17 31 59	15				
		M	17 32 39	10	6			
		F	17 35 41					
25		P	?4 23 58	15				
		L	4 27 43	20				
		M	4 29 40	20	12			
		F	5 03 33					
25		L	12 21 12	15				
		M	12 23 07	15	4			
		F	12 23 47					
28		P & L.	2 28 00					Local; set mirror vibrating, no record obtained; felt all over Victoria, Esquimalt, north to Malahat and James I., also in Vancouver.
		F	2 28 15					
			VERTICAL.					
		P & L.	2 28 00					
		M	2 28 02		1			
		F	2 28 30					
28		L	13 29 19	8				
		M	13 31 37	8	2			
		F	13 32 29					Clock stopped 28th-29th.

CANADA. *Dominion Meteorological Service, Victoria*—Continued.

1922.			VERTICAL. *H. m. s.*	*Sec.*	μ	μ	*Km.*	
Dec. 31		P	7 37 17	15			2,440	
		S	7 41 17	18				
		L	7 46 37	30				
		M	7 55 02	25	40			
		F	9 18 57					

No earthquakes were recorded at the following stations during December, 1922:

COLORADO. *Regis College*, Denver.

NEW YORK, *Fordham University*, New York.

Reports for December, 1922, have not been received from the following stations:

ALABAMA. *Spring Hill College*, Mobile.

ARIZONA. *U. S. C. & G. S. Magnetic Observatory*, Tucson.

DISTRICT OF COLUMBIA. *Georgetown University*, Washington.

MASSACHUSETTS. *Harvard University*, Cambridge.

MISSOURI. *St. Louis University*, St. Louis.

NEW YORK. *Cornell University*, Ithaca.

TABLE 3.—*Late reports (instrumental.)*

ALASKA. *U. S. C. & G. S. Magnetic Observatory, Sitka.*

1922.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Nov. 11		O_1	4 32 38				11,070	Based on PR1 and SR1.
		O_2	4 32 38				10,800	Based on PR2 and SR2.
		PR1$_E$	4 50 43	23	*500			
		ePR1$_N$	4 50 18	10				
		PR2$_E$	4 53 02	28	*400			
		e$_E$	4 56 42		*100			
		e$_N$	4 57 10	12				
		S$_E$?	4 57 45		*500			
		eS$_N$?	4 58 38			*800		
		PS$_E$?	4 59 20	26	*2,000			
		SR1$_E$	5 05 05					
		SR1$_N$	5 05 17	28		*2,000		
		SR2$_E$	5 09 18	20	*4,600			
		SR2$_N$	5 09 14	26		*1,500		
		e$_N$	5 13 05					
		eL1$_E$	5 20 20					
		L2$_E$	5 23 45	25				
		L1$_N$	5 22 20	36				
		L2$_N$	5 25 49	28				
		M$_E$	5 26 53	24	*13,100			
		M$_N$	5 29 41	18		*11,000		
		C$_E$	6 11 ..					
		C$_N$	5 31 ..	16				
		F$_E$	8 12 ..					
		F$_N$	6 44 ..	15				
Nov. 17		e	11 54 08					
		e$_E$	11 56 58					
		L$_E$	11 58 59	18				
		L$_N$	11 58 56	16				
		M$_E$	12 01 00	16	*200			
		M$_N$	12 02 50	15		*100		
		F$_E$	12 16 ..					
		F$_N$	12 35 ..					

ARIZONA. *U. S. C. & G. S. Magnetic Observatory, Tucson.*

1922.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Nov. 11		O	4 32 33				8,120	Based on P_N and S. Recorded on magnetograph; SR1 doubtful; F_E indeterminate on account irregular trace due to loose stylus.
		eP$_E$	4 44 05					
		P$_N$	4 44 00	4		*100		
		S$_E$	4 53 26		*800			
		S$_N$	4 53 26	26		*2,400		
		PS$_E$?	4 54 07					
		PS$_N$?	4 53 54					
		SR1$_E$	4 58 45	32	*200			
		SR2$_E$	5 02 04		*500			
		SR2$_N$	5 02 04	29		*2,000		
		e$_E$	5 03 15	50	*1,500			
		e$_N$	5 03 39					
		eL1$_E$	5 06 59	28	*1,500			
		L2$_E$	5 09 59	17	*1,400			
		L3$_E$	5 10 50	17	*			
		L1$_N$	5 07 18	32		*6,800		
		L2$_N$	5 09 09	20				
		M$_E$	5 11 30	17	*14,000			
		M$_N$	5 11 17	20		*8,300		
		C$_E$	5 12 07					
		C$_N$	5 14 ..	16				
		F$_N$	7 05 ..	12				
17		e$_N$	11 39 12	16				Barely perceptible.
		F$_N$	11 43 ..					

* Trace amplitude.

DISTRICT OF COLUMBIA. *Georgetown University, Washington.*

			H. m. s.	Sec.	μ	μ	Km.	
1922. Nov. 4		e_N	3 29 26					EW does not show; heavy micros.
		eL_N	3 39 48					
		L_N	3 42 29					
		F	4 *ca.*					
7		eP_E	23 11 07					Heavy micros; no distinct M.
		iP_N	23 11 07					
		eS_E	23 19 57					
		iS_N	23 19 58					
		eL_E	23 31 ..					
		L_E	23 41 ..	21				
		L_N	23 40 ..	27				
8		F	0 10 ..					
11		eP_E	4 43 41					
		iP_N	4 43 37					
		iS_E	4 52 32					
		eS_N	4 52 32					
		eL_E	5 00 42	31				
		eL_N	5 01 30	30				
		M_E1	5 04 27		*4,800			
		M_N1	5 10 ..			*2,700		
		M_E2	5 10 24		*10,100			
		M_N2	5 12 11		*4,000			
		F	8 50 ..					
11		e_E?	7 37 44					EW component obscure; rest lost in cauda of preceding quake.
		e_N	7 37 44					
		S_N?	7 46 40					
11		eP_E	18 20 21					Heavy micros; no distinct M.
		iP_N	18 20 23					
		iS_E	18 29 16					
		eS_N	18 29 15					
		eL_E	18 50 18					
		eL_N	18 50 24					
		F	19 10 ..					
17		eP_E	11 13 02					Do.
		eP_N	11 13 02					
		S_E	11 22 00					
		S_N	11 22 02					
		eL_N?	11 40 36					
		L_N	11 42 30	21				
		F	12 15 ..					

HAWAII. *U. S. C. & G. S. Magnetic Observatory, Honolulu.*

			H. m. s.	Sec.	μ	μ	Km.	
1922. Nov. 4		e	3 33 55					
		L_E	3 34 57					
		L_N	3 35 07					
		M_E	3 36 07	9	15			
		M_N	3 36 07	10		16		
		F_E	3 38 45					
		F_N	3 39 07					
7		P_E	23 24 27					Preliminary phases poorly defined; may be S, PS, SR, and SR_2, indicating Chile as origin; L well defined.
		$PR1_E$	23 26 33					
		$PR1_N$	23 27 05					
		S_E	23 32 10					
		e_N	23 37 25					
		L_E	23 44 55	23				
		L_N	23 44 48	21				
		M_E	23 47 00	21	64			
		M_N	23 46 36	21		38		
8		F_E	0 50 ..					
		F_N	0 52 ..					
11		O_1	4 32 43				11,000	Based on iPR1 and $iSR1_E$.
		O_2	4 32 22				11,300	Based on PS and P.
		O_3	4 33 20				10,050	Based on P_E and S (?).
		P_E	4 46 25					
		eP_N	4 46 30					
		PR1	4 50 21					
		i	4 50 40					
		PR2	4 52 44	10	24	32		
		iS(?)	4 57 25					
		iPS	4 59 32					
		$SR1_E$	5 03 45	20	480			
		$SR1_N$	5 03 50	25		295		
		i_E	5 05 00					
		$SR2_E$	5 10 15	30				
		$SR2_N$	5 09 25	30				
		$L1_E$	5 13 45					
		$L1_N$	5 13 30					
		$L2_E$	5 17 22	25				
		$L2_N$	5 17 22	20				
		M_E	5 18 ..	25	2,060			
		M_N	5 19 57	20		730		
		$LR2_E$	8 12 20	21	52			
		$LR2_N$	8 12 10	21		21		
		F	8 50 *ca*					
17		iP_N	11 27 18					First two phases may be S and SR1, indicating Chile; well-defined change of activity at 11:29:28 may be PS.
		Pe(?)	11 27 08					
		S	11 34 50					
		L_E	11 47 18	24				
		$L1_N$	11 43 55					
		$L2_N$	11 46 55					
		$L3_N$	11 48 09	22				
		M_E	11 49 ..	20	77			
		M_N	11 49 ..	22		46		
		C_E	11 57 ..					
		C_N	11 53 ..					
		F	13 03 ..					

*Trace amplitude.

HAWAII. *U. S. C. & G. S. Magnetic Observatory, Honolula*—Contd.

			H. m. s.	Sec.	μ	μ	Km.	
1922. Nov. 21		i	13 59 00					Local shock; light eclipsed from 14:00:40 to 14:01:00.
		M_E	14 00 20	2	47			
		M_N	14 00 08	2		21		
		F_E	14 05 ..					
		F_N	14 03 ..					
22		i_E	15 03 48	13				Trace very irregular; range of motion 5.0 mm.
		e_N	15 05 30					
		M_E	15 04 50					
		F_E	15 08 ..					
		F_N	15 11 ..					

MARYLAND. *U. S. C. & G. S. Magnetic Observatory, Cheltenham.*

			H. m. s.	Sec.	μ	μ	Km.	
1922. Nov. 11		O	4 32 46				7,320	Based on P_N and S; actual M occurs at 4:53:20 during S.
		eP_E	4 43 47	3	*100			
		P_N	4 43 31	3		*200		
		$PR1_N$	4 46 34					
		$PR2_N$	4 48 09					
		S_E	4 52 16	31	*3,500			
		S_N	4 52 16			*1,000		
		PSe?	4 52 49					
		$SR1_E$	4 57 39	14	*1,400			
		$SR1_N$	4 57 39	15		*700		
		$SR2_E$	4 59 53	30	*2,900			
		$eSR2_N$	5 00 18	32		*1,100		
		$eL1_E$	5 06 50	25	*2,100			
		$eL2_E$	5 09 32	22				
		$L1_N$	5 07 34					
		$eL2_N$	5 13 10	20				
		M_E	5 10 15	22	*2,300			
		M_N	5 14 31	20		*3,800		
		C_E	5 14 ..					
		F_E	7 21 ..					
		F_N	7 28 ..					

CANAL ZONE. *Panama Canal, Balboa Heights.*

			H. m. s.	Sec.	μ	μ	Km.	
			25-KILOGRAM RECORD.					
1922. Nov. 7								Slight tremors from distant disturbance, 22:03 to 22:45; distance and direction unknown.
10		P_E	14 39 18				320*ca*	Probably SW.
		P_N	14 39 24					
		S_E	14 39 52					
		S_N	14 39 58					
		L_E	14 40 08					
		M_E	14 40 12		*1,000			
		M_N	14 40 40			*500		
		F	14 45 00					
11		P_E	4 40 10				3,400*ca*	Direction SE.
		P_N	4 40 04					
		S_E	4 45 40					
		S_N	4 46 00					
		L_E	4 49 36					
		L_N	4 49 12					
		M_E	4 49 58		*7,000			
		M_N	4 49 48			*6,000		
		F_E	6 43 00					
		F_N	6 35 00					
17							4,000*ca*	Too small to measure; direction southerly.
			100-KILOGRAM RECORD.					
7								Slight tremors from distant disturbance 22:03 to 22:45; distance and direction unknown.
10		P_E	14 39 22				320*ca*	Probably SW.
		P_N	14 39 20					
		S_E	14 39 56					
		S_N	14 39 54					
		M_E	14 40 24		*5,000			
		M_N	14 40 00			*4,000		
		F_E	14 46 00					
		F_N	14 47 00					
11		P_E	4 40 26				4,300*ca*	Direction SE.
		P_N	4 40 00					
		S_E	4 46 14					
		S_N	4 46 08					
		L_E	4 49 26					
		L_N	4 49 28					
		M_E	4 49 46		*14,000			
		M_N	4 53 38			*16,000		
		F_E	6 44 00					
		F_N	6 45 00					
17		P_N	11 10 20				4,000*ca*	Southerly. EW record too small to measure.
		S_N	11 16 05					
		M_N	11 24 00			*500		
		F_N	12 30 00					

*Trace amplitude.

PORTO RICO. *U. S. C. & G. S. Magnetic Observatory, Vieques.*

1922.			H. m. s.	Sec.	μ	μ	Km.	
Nov. 4		e_E	5 38 17	4	*100			Local shock recorded on H variometer.
		e_N	5 37 57					
		e_N	5 38 32	4		*100		
		F_E	5 40 36					
		F_N	5 42 ..					
11		O	4 32 34				5,050	Based on P_N and S_N; recorded on magnetograph.
		eP_E	4 41 11	4				
		eP_N	4 41 05					
		P_E	4 43 13	10		*3,000		
		e_N	4 45 41					
		eS_E	4 48 12	12	*3,000			
		S_N	4 47 50	20		*6,700		
		PS_E?	4 48 38					
		$SR1_E$	4 51 15	15	*13,500			
		$eSR1_N$	4 51 37			*8,000		
		$L1_E$	4 56 28	22				
		$L2_E$	4 58 12	26				
		$eL1_N$	4 58 15	20		*26,200		
		$eL2_N$	5 02 00	20				
		i_N	4 59 35					
		M_E	5 02 20	20	*32,000			
		M_N	5 04 ..	18		*80,000		Trace off paper.
		C_E	5 03 15	18				
		C_N	5 17 ..	18				
		F_E	8 00 ..					
		F_N	7 40 ..					
19		e	9 57 48			*100		Local; felt in Vieques.
		F_E	9 58 11					Record very faint.
		F_N	9 58 34					

CANADA. *Dominion Observatory, Ottawa.*

1922.			H. m. s.	Sec.	μ	μ	Km.	
Nov. 4		$e?_E$	3 32 ..					
		eL	3 40 ..					
		L	3 41 18	10				
		F	3 50 ..					
7		O	23 00 23					
		P	23 11 47				8,060	
		S	23 21 10					
		$eL?_E$	23 31 ..					
		eL_N	23 34 ..					
		L	*23 37 ..	18				
		L	23 43 ..	20				
		L	23 50 ..	19				
		L	23 53 ..	17				Good record on vertical.
8		F	1 00 *ca.*					
9		eL_E	0 09 ..					Faint traces of L waves on vertical.
		L_E	0 10 ..	22				
		L_E	0 13 ..	18				
		F	0 26 ..					
11		O	4 32 37				8,230	Well recorded on vertical.
		iP	4 44 10					
		S	4 53 42					
		$SR2?_E$	5 03 *ca.*					
		eL?	5 08 24					
		$M1_E$	5 12 30	25				
		$M1_N$	5 16 ..	19				
		$M2_E$	5 22 ..	17				
		$M2_N$	5 25 30	17				
		$M3_{NE}$	5 38 ..	17				
		$M4_{NE}$	5 44 ..	17				
		F	9 20 *ca.*					
			HALIFAX RECORD.					
		O	4 32 58				8,200	
		eP	4 44 33					
		$PR2_E$	4 49 23					
		S_E	4 54 00					
		$SR2?_E$	5 02 28					
		eL_E	5 08 30					
		L_E	5 19 30					
		L_E	5 35 ..					
		L_E	5 44 30					
		F	7 48 *ca.*					
11		O	18 09 33				8,080	
		P_V	18 20 58					
		S_E	18 30 22					
		eL	18 44 30					
		L_E	18 49 ..					
		L	18 53 ..	20				
		L	18 57 16	16				
		L	19 02 ..	16				
		F	19 32 ..					
12		i	7 30 22					
		F	7 55 ..					
17		O	11 03 15				8,020	
		P_V	11 14 37					
		S_E	11 23 58					
		eL_E	11 35 ..					
		L	11 37 ..	20				
		L	11 46 ..	17				
		L	11 50 ..	17				
		L	11 55 ..	15				
		L_E	11 59 ..	17				
		L_E	12 07 ..	15				
		F	13 00 *ca*					
22		eL_E	15 42 ..					
		L_E	15 47 ..	18				
		F	15 55 *ca*					

* Trace amplitude.

CANADA. *Dominion Meteorological Service, Toronto.*

1922.			H. m. s.	Sec.	μ	μ	Km.	
Nov. 4		iL	3 40 00					
		F	4 01 00		*300			
7		P?	23 10 18					
		S	23 21 54					
		iL	23 31 12					
		L	23 51 24					
		M	23 52 36		*800			
		eL	23 56 42					
8		eL	0 16 00					
		eL	0 27 12					
		F	1 08 36					
9		L	0 23 12		*50			
		F	0 32 24					
11		O	4 32 29					Chili; groups of large vibrations from 5*h*. to 5:46 followed by smaller groups.
		P	4 43 54					
		i	4 47 00					
		S	4 53 18					
		i	5 03 18					
		i	5 05 00					
		iL	5 08 30					
		iL	5 25 24					
		iL	5 25 42					
		M	5 29 42		*9,600		8,080	L 8:21:48.
		F	9 48 06					L 8:32:06.
11		P	18 21 00?					P and S indistinct.
		S	18 29 18?					
		L	18 39 30					
		eL	18 57 18					
		M	19 00 36		*300			
		eL	19 11 54					
		F	19 30 30					
12		L	8 04 00		*50			
17		P	11 15 00?				7,490	P not well defined; amplitude of S large.
		S	11 23 54		*400			
		L	11 33 00					
		L	11 49 30					
		L	11 52 36					
		M	11 57 42		*500			
		F	14 06 24					
26		L	13 51 30					
		F	14 08 42		*50			

CANADA. *Dominion Meteorological Service, Victoria.*

1922.			H. m. s.	Sec.	μ	μ	Km.	
Nov. 4		L	3 21 48					
		M	3 23 17		*300			
		F	3 33 42					
		P	3 20 46	10			180?	MILNE-SHAW E.
		L	3 21 11	25				
		M	3 23 11	12.	19			
		F	3 37 00?					
7		O	23 00 19				9,470	Probably Chile.
		P	23 12 55					
		S	23 23 29					
		L	23 39 51					
		M	23 50 46		*2,500			
8		F	1 47 47					
		O	23 00 55					MILNE-SHAW EW.
		P	23 13 20	12			9,240	Probably Chile.
		S	23 23 45	20				
		L	23 40 00	30				
		M	23 50 35	20	83			
		F	1 38 54					
9		M	0 31 58		*200			
		L	0 41 59	20				MILNE-SHAW EW.
		M	0 46 34	20	6			
9		P	12 57 11	5				Do.
		L	12 58 06	10				
		M	12 58 31	15	6			
		F	13 03 41					
11		O	4 32 59				9,920	Chile.
		P	4 45 57					
		S	4 56 51					
		L	5 18 10					
		M	5 22 08		*17000			
		F	10 18 40					
		O	4 33 05				10,060	Chile.
		P	4 45 40	12				MILNE-SHAW EW.
		S	4 56 12	20				
		L	5 11 12	45				
		M	5 21 57	30	1,775			
		F	10 24 57					
			VERTICAL.					
		P	4 45 40	5			9,930	Chile.
		S	4 56 35	12				
		L	5 15 10	30				
		M_z	5 19 55	25	40			
		F	7 29 55					

* Trace amplitude.

CANADA. *Dominion Meteorological Service, Victoria*—Continued.

			VERTICAL.					
			H. m. s.	*Sec.*	μ	μ	*Km.*	
1922. Nov. 11.	....	P_Z.....	18 32 45	....	....	....	7,310	Probably Chile.
		S_Z.....	18 41 30	....	....	....	....	
		L_Z.....	18 56 23	....	....	....	....	
		M_Z.....	19 00 21	....	*1,000	....	....	
		F_Z...3	20 19 41	....	....	....	....	
Remainder of records are from Milne-Shaw, E-W:								
11	....	P.....	18 22 29	12	....	....	9,820	Probably Chile.
		S.....	18 33 19	15	....	....	....	
		L.....	18 49 44	25	....	....	....	
		M.....	18 59 54	20	25	....	....	
		F.....	20 56 24	....	....	....	....	
12	....	P.....	7 32 54	10	....	....	4,770	
		S.....	7 39 24	15	....	....	....	
		L.....	7 54 54	20	....	....	....	
		M.....	8 00 04	15	4	....	....	
		F.....	8 32 20	15	....	....	....	
13	....	P.....	4 26 23	12	....	....	....	
		L.....	5 01 03	15	....	....	....	
		M.....	5 04 08	15	3	....	....	
		F.....	5 18 18	15	....	....	....	
14	....	L.....	6 10 09	30	....	....	....	
		M.....	6 32 29	25	1	....	....	
		F.....	6 44 14	....	....	....	....	
17	....	P.....	11 16 20	10	....	....	....	
		S.....	11 26 35	15	....	....	....	
		L.....	11 42 50	50?	....	....	990	Chile(?).
		M.....	11 53 40	25	161	....	....	
		F.....	13 46 25	....	....	....	....	
22	....	L.....	?15 22 53	25	....	....	....	
		M.....	15 26 23	20	4	....	....	
		F.....	15 40 33	20	....	....	....	
26	....	P.....	13 53 59	10	....	....	....	
		L.....	14 14 59	35	....	....	....	
		M.....	14 16 24	30	15	....	....	
		F.....	15 03 49	....	....	....	....	

*Trace amplitude.

EARTHQUAKES FELT IN THE UNITED STATES DURING 1922.

(Consult also Chart 168 in this issue.)

During the calendar year 1922, 84 separate earthquakes strong enough to be felt by the unaided senses were reported from different parts of the continental United States, as listed in the accompanying table and graphically represented (a dot for each *report*, not for each separate quake) on Chart 168 at the end of this issue of the REVIEW.

Earthquakes of reported intensity 5 or greater (adapted Rossi-Forel scale), not accompanied by appreciable damage, occurred in Arizona on June 15–17; in California, January 31, February 5, March 10 and 16, June 16, August 18, September 5; in Illinois, March 22–23; in Indiana, January 11; in Kentucky, March 22–23; in Missouri, March 22–23; in Oregon, January 31; in South Dakota, January 2; in New York, December 8; and in Tennessee on March 22, 23, 30.

The earthquake of January 31 was of marked intensity, but the epicentre was apparently in the Pacific Ocean, off the California coast. Widespread shocks occurred on March 22 in Arkansas, Illinois, Indiana, Kentucky, Missouri, and Tennessee; on March 30 in Illinois, Kentucky, Missouri, and Tennessee; and on November 26 in Kentucky, Tennessee, Illinois, Indiana; but all these were of slight intensity.—*E. W. Woolard.*

Places in the United States reporting earthquakes during 1922.
[Consult also Chart 168 in this issue.]

Place.	Approximate latitude N.	Approximate longitude W.	Number quakes reported.
ARIZONA.			
Payson	34 10	111 06	1
Roosevelt	33 40	111 00	1
Young	34 05	111 00	1
Yuma	32 40	114 35	4
ARKANSAS.			
Blytheville	35 53	89 55	1
Corning	36 35	90 30	1
Jonesboro	35 55	90 35	1
Knobel	36 15	91 00	1
Marmaduke	36 10	90 20	1
Paragould	36 05	90 30	1
Peach Orchard	36 15	90 40	1
Pocahontas	36 15	91 00	1
Walnut Ridge	36 05	91 00	1
Weiner	35 37	90 50	1
Wilson	35 37	90 00	1
CALIFORNIA.			
Amos	33 05	115 16	1
Angiola	36 00	119 30	1
Antelope Valley	....	....	2
Atascadero	35 20	120 30	4
Bakersfield	35 22	119 00	1
Brawley	32 59	115 40	2
Calexico	32 41	115 30	12
Cholame	35 35	120 10	1
Cloverdale	38 45	123 00	1
Coalinga	36 00	120 15	1
Dudley	35 45	120 00	1
Escondido	33 06	117 05	1
Eureka	40 48	124 10	8
Fort Bragg	39 30	123 50	1
Fresno	36 40	120 00	1
Grass Valley	39 15	121 00	1
Hollister	36 45	121 20	3
Julian	33 05	116 37	2
Lindsay	36 20	119 15	1
Los Alamos	34 45	120 15	6
Los Angeles	34 03	118 15	1
Los Gatos	37 12	121 58	1
McCloud	41 15	122 10	1
Maricopa	35 05	119 23	1
Nevada City	39 15	121 00	1
Oakland	37 38	122 15	1
Paso Robles	35 40	120 30	10
Petaluma	38 15	122 38	1
Quincy	40 00	121 00	1
Red Bluff	40 10	122 15	1
Redding	40 35	122 25	1
Riverside	33 58	117 21	1
Ruth	40 20	123 20	1
Salinas	36 41	121 39	4
San Francisco	37 48	122 26	2
San Luis Obispo	35 13	120 45	4
Santa Ana	33 45	117 45	1
Spreckles	36 38	121 36	3
Springville	36 00	119 00	1
Shando	35 30	120 10	2
Simmler	35 15	120 00	1
Whittier	34 00	118 00	1
Willows	34 03	118 15	1
Yorba Linda	33 50	117 45	2
IDAHO.			
Bennett	43 20	115 30	1
Wayan	43 00	111 20	1
ILLINOIS.			
Anna	37 30	89 15	2
Cairo	37 00	89 05	4
Clinton	40 10	89 00	1
Eldorado	37 50	88 30	1
Harrisburg	37 45	88 35	1
McLeansboro	38 07	88 33	1
Monmouth	40 50	90 40	1
New Burnside	37 35	88 50	2
Waterloo	38 20	90 12	1
White Hall	39 25	90 30	1
INDIANA.			
Bedford	38 55	86 30	1
Mt. Vernon	38 00	88 00	2
Terre Haute	39 30	87 25	1
KENTUCKY.			
Arlington	36 50	89 00	
Bardwell	36 52	89 01	3
Blandville	37 00	89 00	1
			3
Clinton	36 45	89 00	3
Columbus	36 45	89 05	2
Fulton	36 30	88 50	2
Hickman	36 34	89 12	4
Hopkinsville	36 50	87 30	2
Leitchfield	37 30	86 20	1
Louisville	38 15	85 45	1
Marion	37 20	88 05	3
Mayfield	36 45	88 40	3
Murray	36 40	88 15	1
Owensboro	37 50	87 00	1
Paducah	37 05	88 40	3
Wycliffe	37 00	89 05	4
MAINE.			
North Perry	45 00	67 00	1
Wytopitlock	45 40	68 05	1
MICHIGAN.			
Port Huron	43 00	82 30	1
MISSOURI.			
Jackson	37 30	89 40	2
New Madrid	36 35	89 32	3
Poplar Bluff	36 50	90 25	3
MONTANA.			
Helena	46 40	112 00	1
Missoula	46 55	114 00	1
NEW HAMPSHIRE.			
Pittsfield	43 20	71 20	1
NEW YORK.			
Canton	44 30	75 10	1
OREGON.			
Ashland	42 20	122 45	1
Bend	44 00	121 20	1
Brookings	42 00	124 15	1
Central Point	42 20	123 00	1
Chiloquin	42 40	122 00	1
Cottage Grove	43 40	123 00	1
Eugene	44 00	123 00	1
Florence	44 00	124 00	1
Hermiston	46 00	119 20	1
Medford	42 20	122 50	1
Oakridge	43 40	122 30	1
Portland	45 30	122 40	1
Port Orfard	42 40	124 30	1
Prospect	42 40	122 30	1
Talent	42 10	122 50	1
Williams	42 10	123 10	1
Winchester Bay	43 15	123 25	1
Wolf Creek	42 40	123 10	1
SOUTH CAROLINA.			
Summerville	33 05	80 15	2
SOUTH DAKOTA.			
Chamberlain	43 45	99 20	1
TENNESSEE.			
Arcadia	36 30	82 30	2
Brownsville	35 40	89 15	1
Clarksville	36 30	87 25	1
Dickson	36 10	87 30	1
Farmington	35 30	86 45	1
Memphis	35 10	90 00	3
Nashville	36 10	86 45	1
Troy	36 20	89 07	2
Union City	36 30	89 00	2
WASHINGTON.			
Clearbrook	49 00	122 10	1
Republic	48 40	118 40	1
Stabler	45 50	122 00	1
Tonasket	48 45	119 30	....
WISCONSIN.			
Fond du Lac	43 50	88 30	1
WYOMING.			
Buffalo	44 20	106 40	1
Casper	43 00	106 20	1
Yellowstone Park	45 00	110 40	1

Chart I. Tracks of Centers of Anticyclones, December, 1922. (Inset) Departure of Monthly Mean Pressure from Normal.

(Plotted by Wilfred P. Day.)

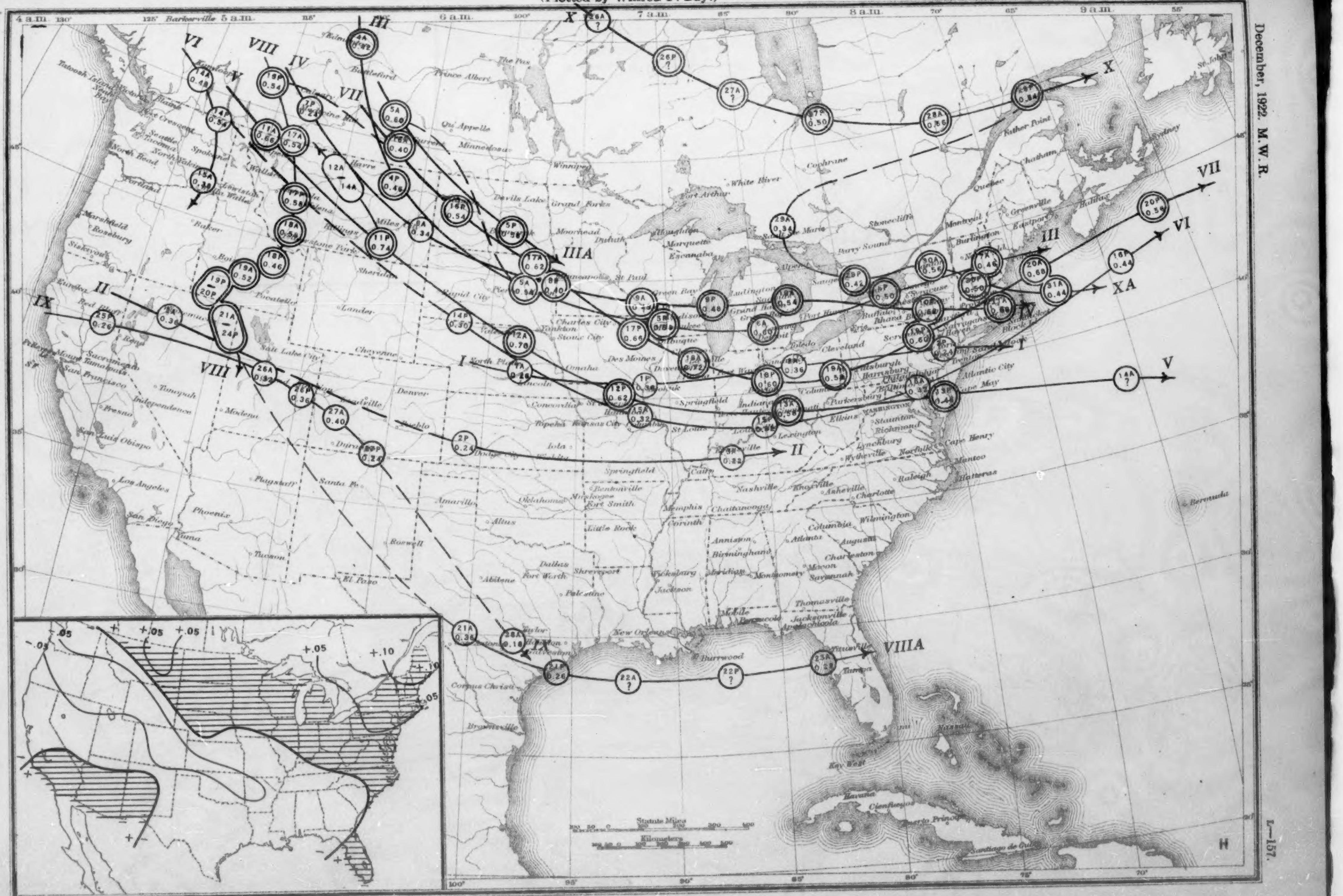


Chart II. Tracks of Centers of Cyclones, December, 1922. (Inset) Change in Mean Pressure from Preceding Month.
(Plotted by Wilfred P. Day.)

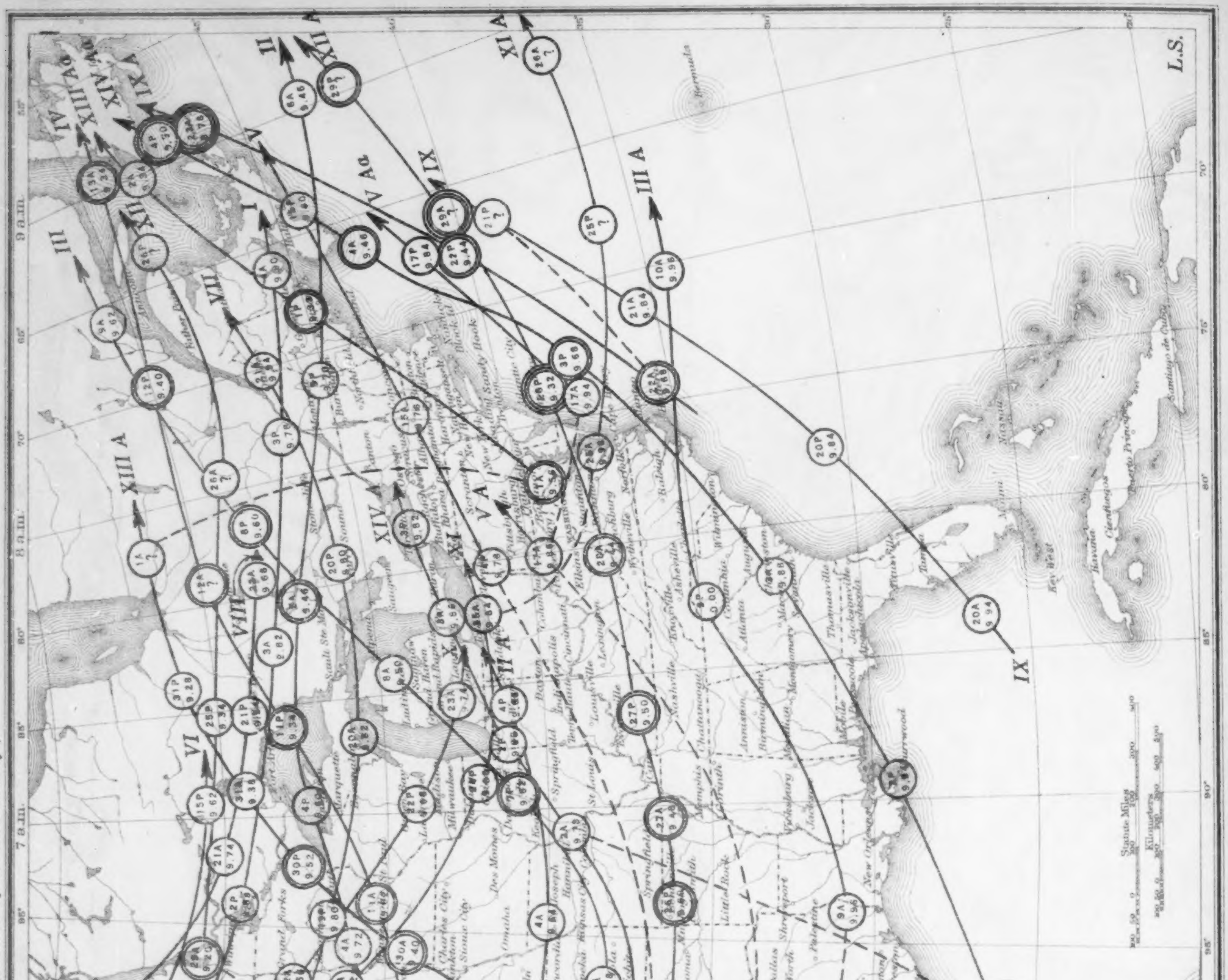


Chart III. Departure (°F.) of the Mean Temperature from the Normal, December, 1922.

Chart IV. Total Precipitation, Inches, December, 1922. (Inset) Departure of Precipitation from Normal.

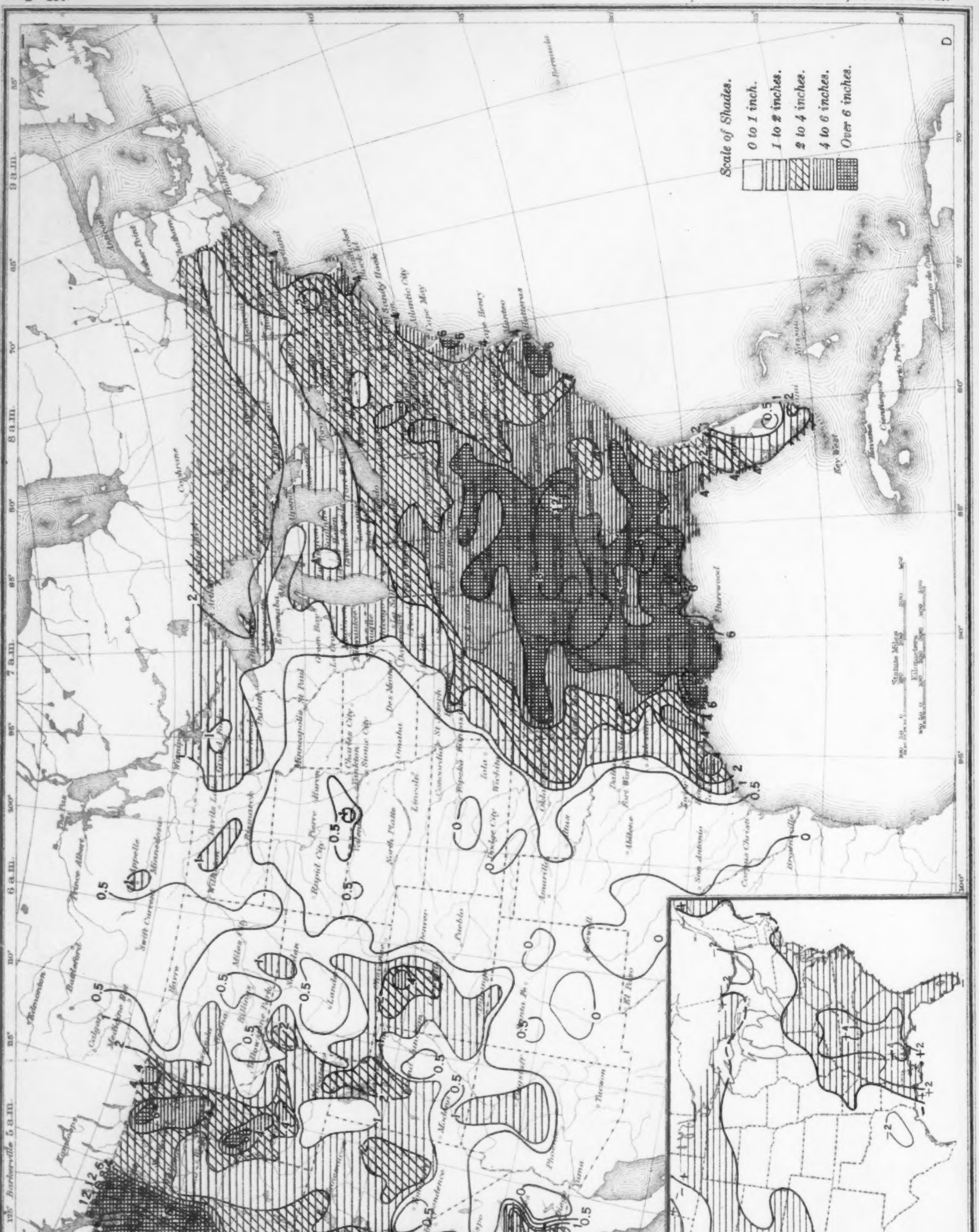


Chart V. Percentage of Clear Sky between Sunrise and Sunset, December, 1922.

Chart VI. Isobars at Sea-level and Isotherms at Surface; Prevailing Winds, December, 1922.

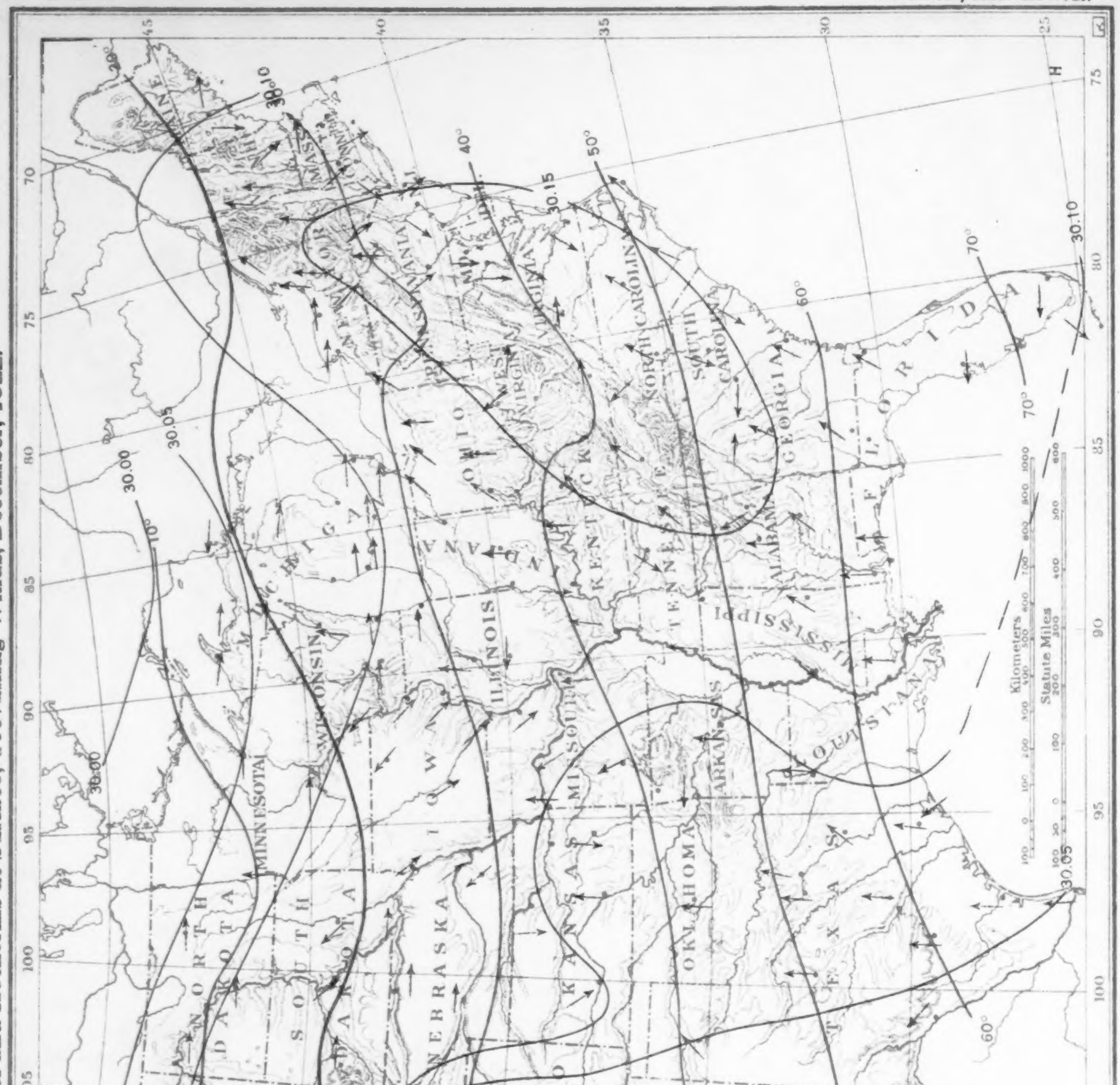
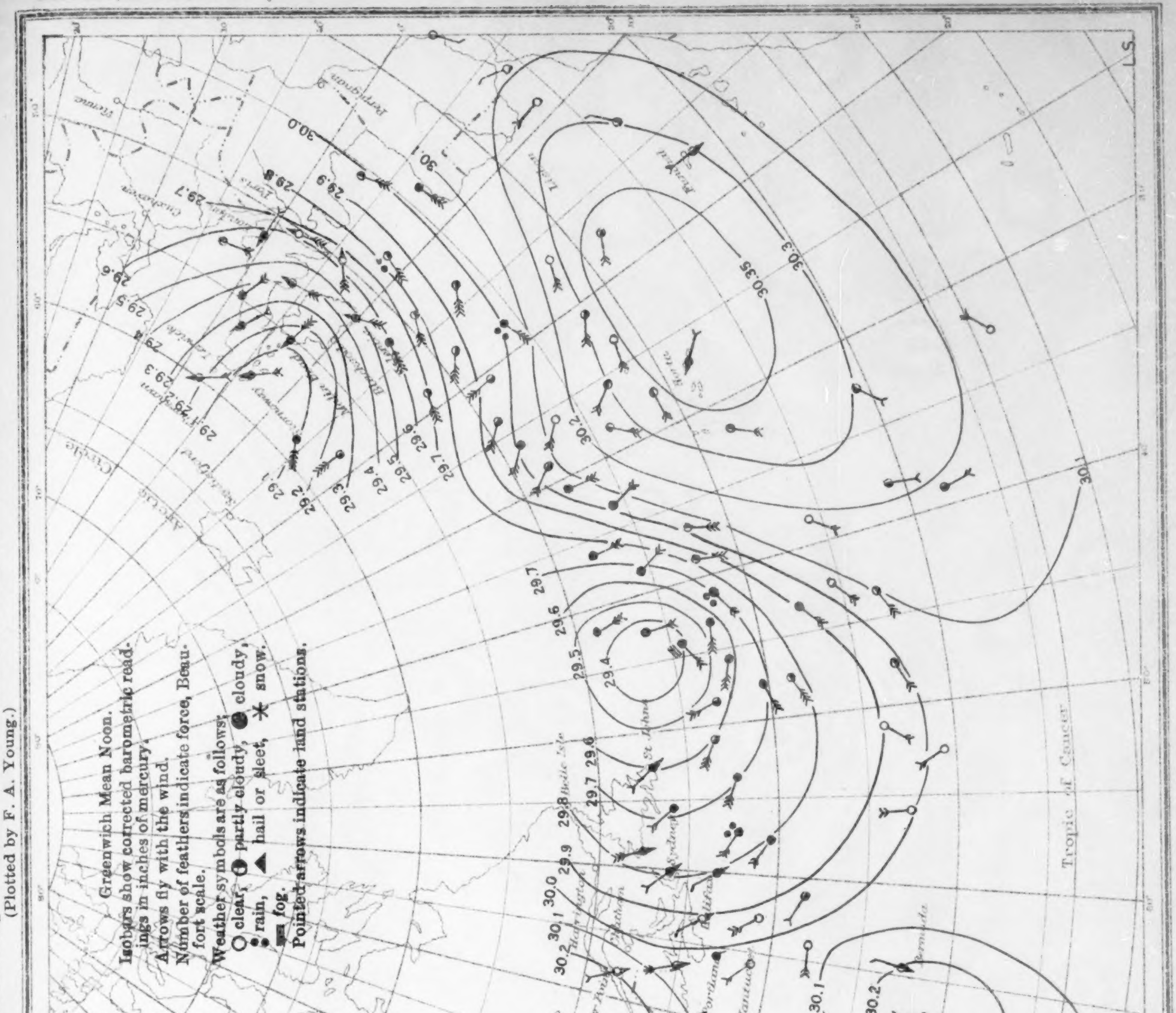


Chart VII. Total Snowfall, Inches, December, 1922. (Inset) Depth of Snow on Ground at end of Month.

Chart VIII. Weather Map of North Atlantic Ocean, December 27, 1922.

Chart VIII. Weather Map of North Atlantic Ocean, December 27, 1922.
(Plotted by F. A. Young.)



Greenwich Mean Noon.
Isobars show corrected barometric readings in inches of mercury.
Arrows fly with the wind.
Number of feathers indicate force, Beaufort scale.
Weather symbols are as follows: ○ clear, ◑ partly cloudy, ● cloudy, ⁝ rain, ▲ hail or sleet, ✱ snow, fog.
Pointed arrows indicate land stations.

Chart IX. Weather Map of North Atlantic Ocean, December 28, 1922.
(Plotted by F. A. Young.)

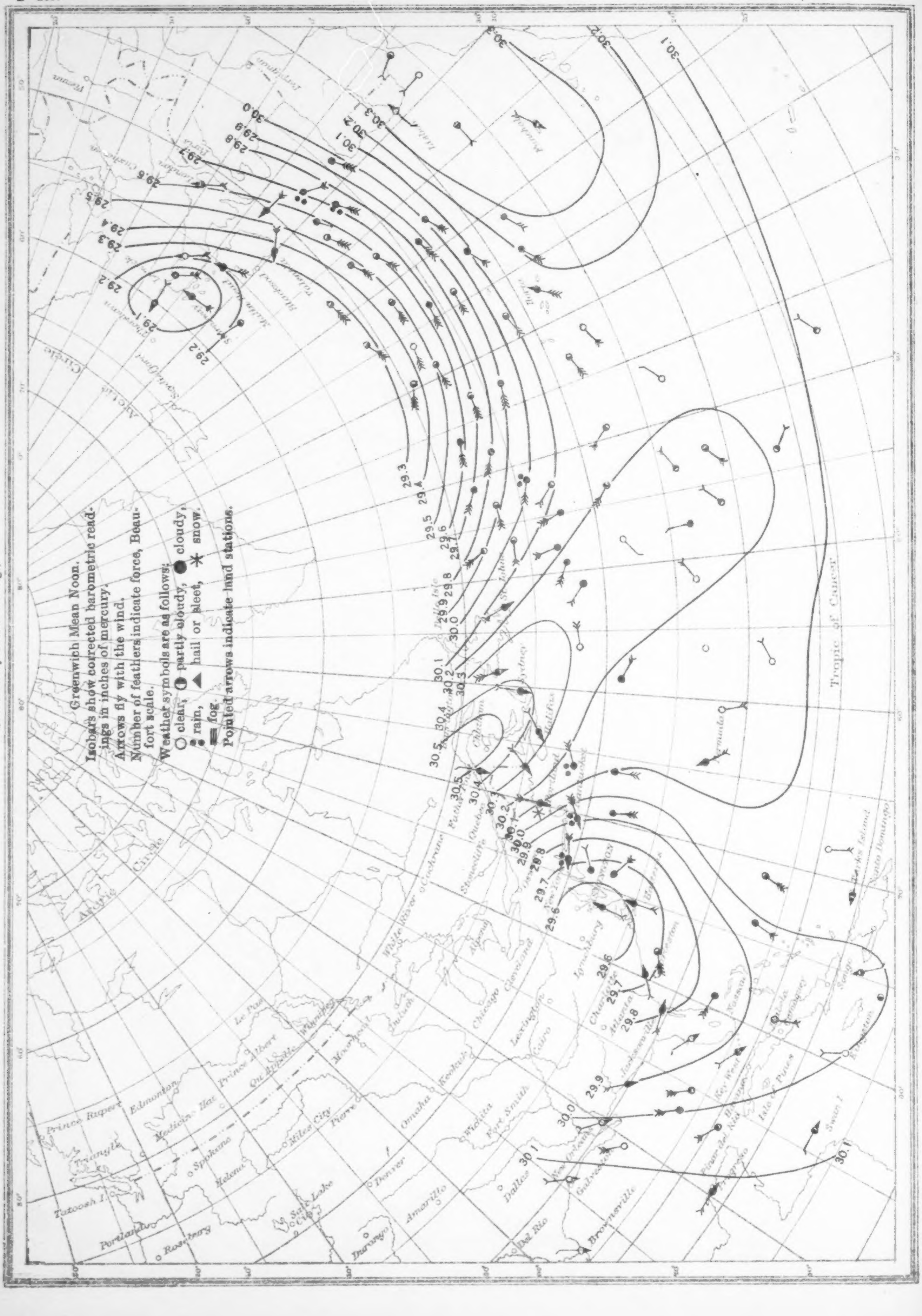


Chart X. Weather Map of North Atlantic Ocean, December 29, 1922.

(Plotted by F. A. Young.)

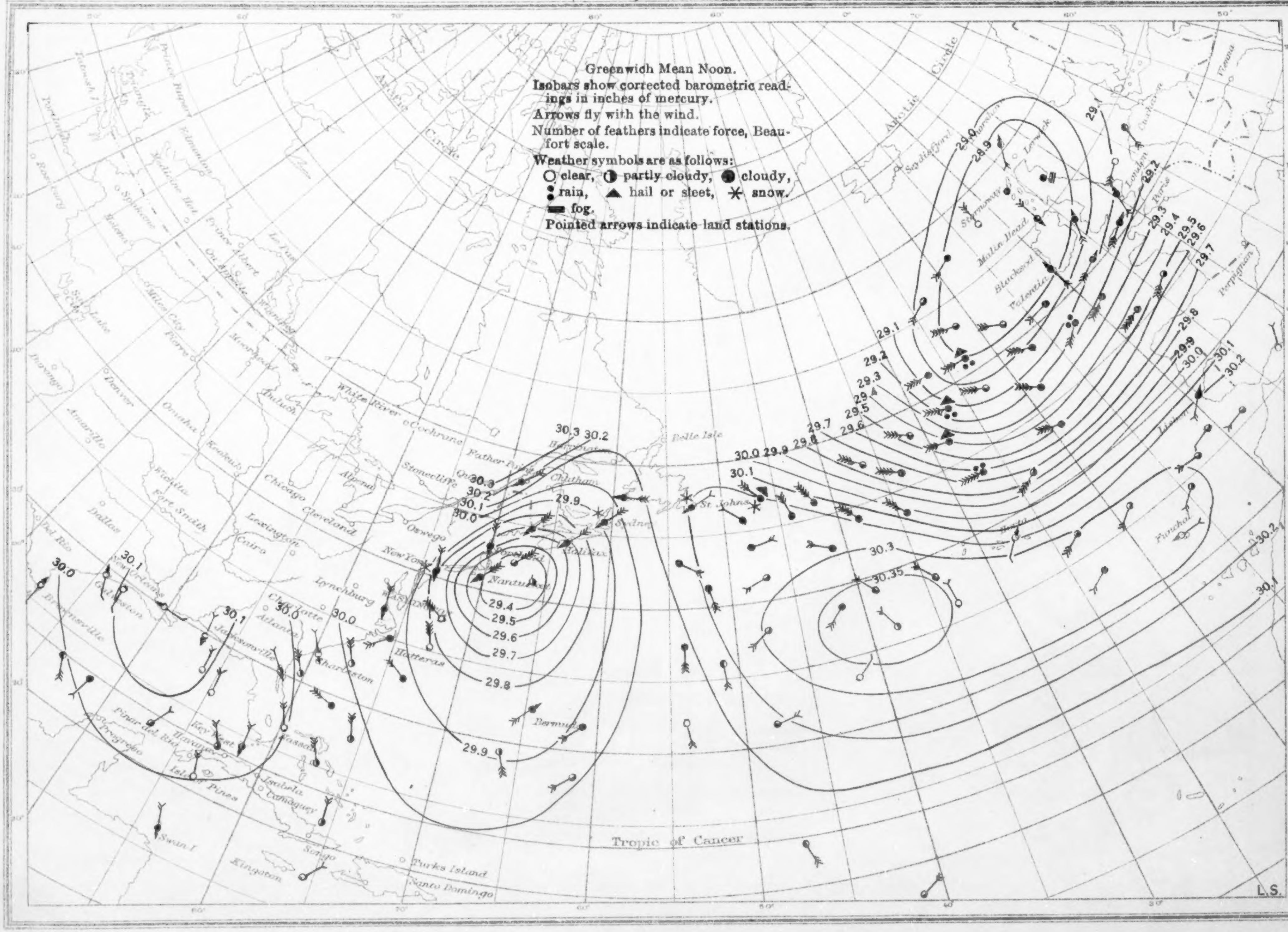


Chart XI. Weather Map of North Atlantic Ocean, December 30, 1922.
(Plotted by F. A. Young.)

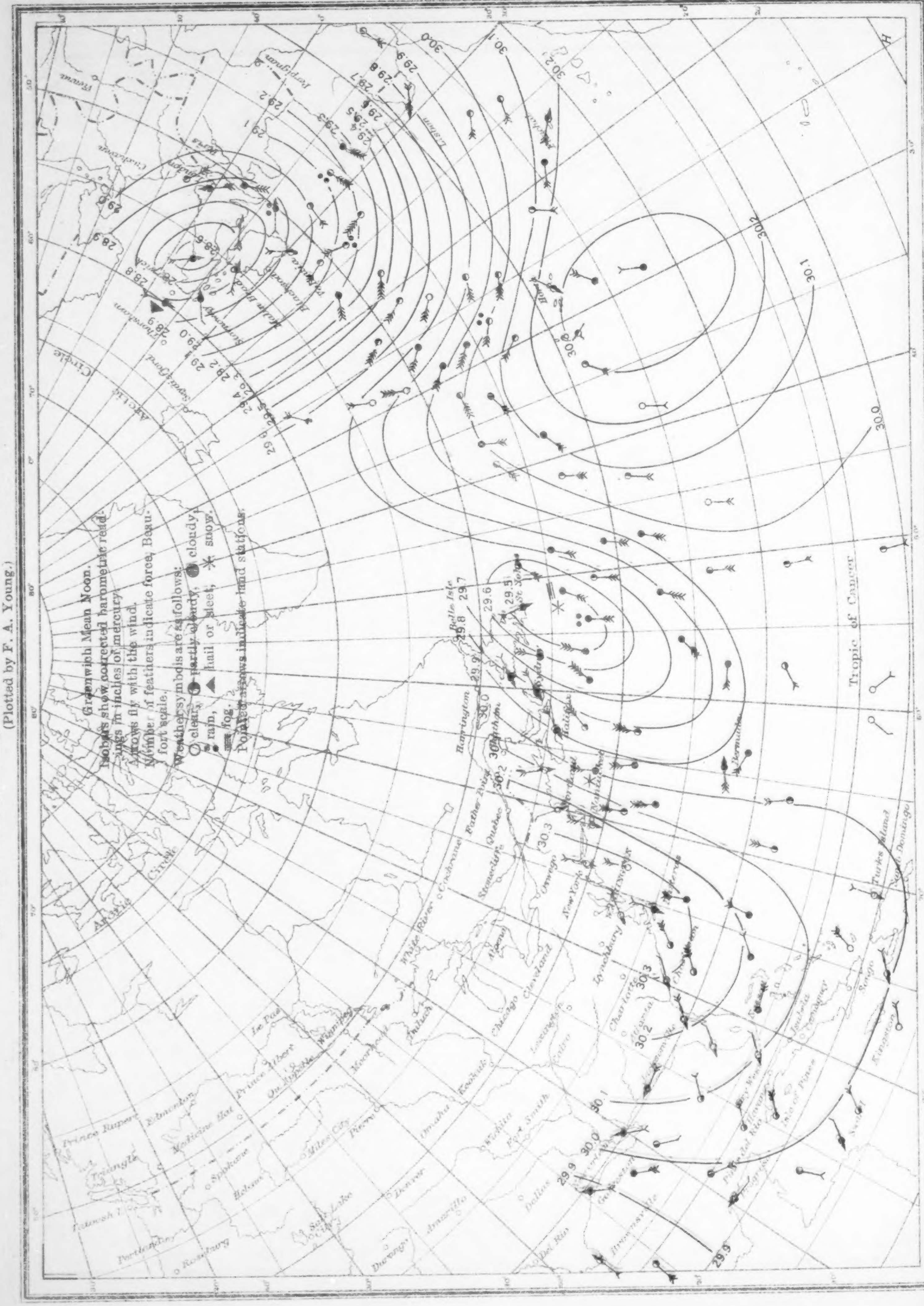


Chart XII. Hurricanes during 1922.

(Plotted by W. P. Day.)

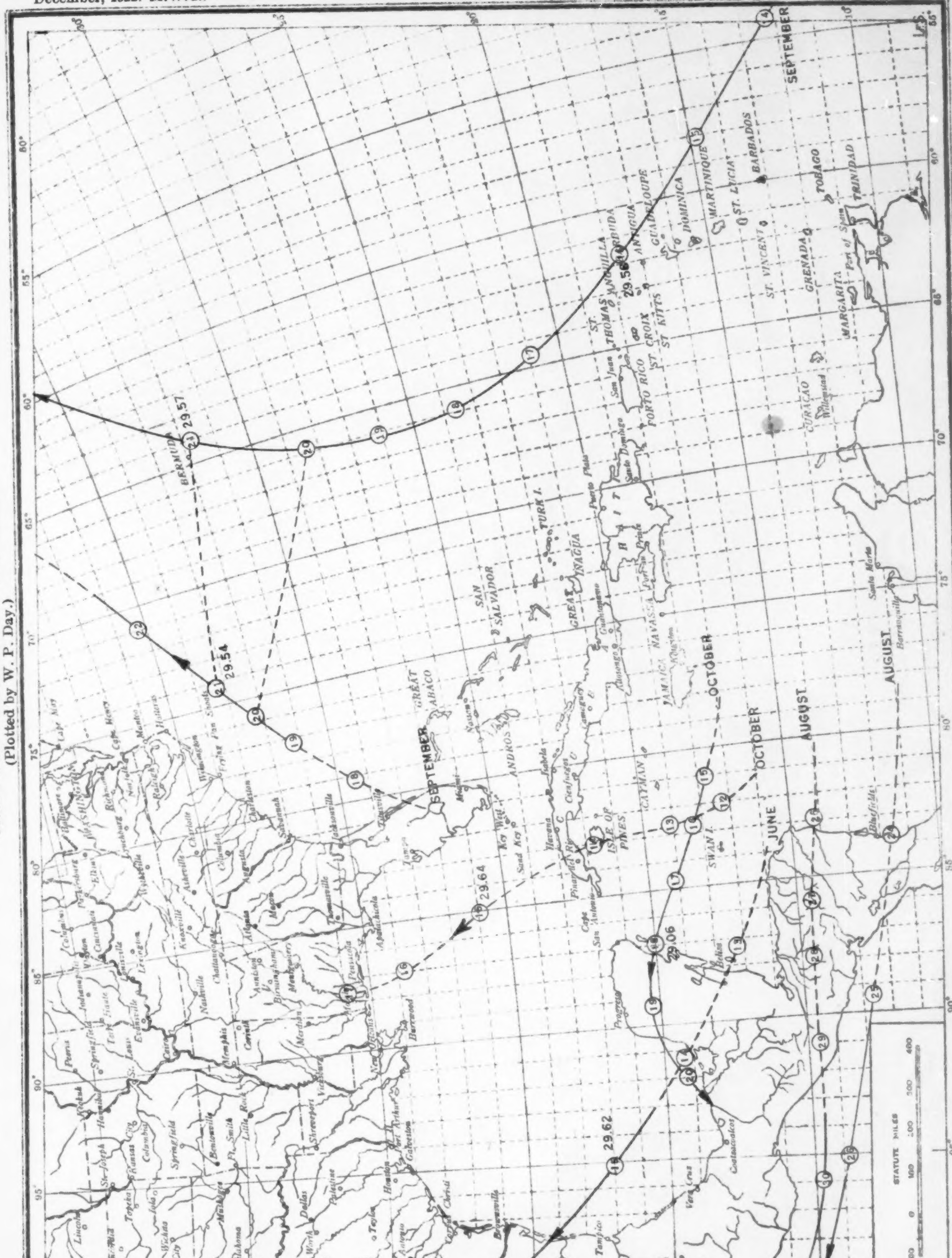


Chart XIII. Earthquakes in the United States during 1922.
(Plotted by E. W. Woolard.)

Chart XIII. Earthquakes in the United States during 1922.

(Plotted by E. W. Woolard.)

SUBJECT AND AUTHOR INDEX OF THE MONTHLY WEATHER REVIEW, 1922. VOL. 50.

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DECEMBER, 1922.

CONTENTS.

CONTRIBUTIONS, ABSTRACTS, AND BIBLIOGRAPHY.

WEATHER OF THE MONTH.

CHARTS.

† In marine separate.

CORRIGENDA.

Review, May, 1922:
Page 266, first column, second paragraph, first line, "Anticyclones" *should read* "Cyclones."

Review, June, 1922:
Page 334, Lower Lake Region, temperature departure *should be* "+0.8."

Review, November, 1922;
Page 574, second column, just below middle of page, the equation *should read:* $b = (a + 2b + c)/4$.